

NAVAL AIR WARFARE CENTER WEAPONS DIVISION

DEPARTMENT OF THE NAVY

PERFORMANCE SPECIFICATION

FOR THE

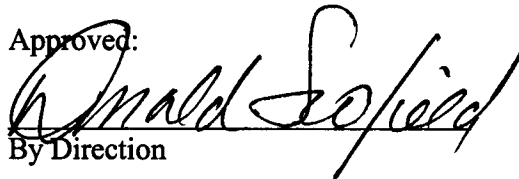
JOINT ADVANCED MISSILE INSTRUMENTATION (JAMI)

TIME SPACE POSITION INFORMATION (TSPi) UNIT

JTU ASSEMBLY – HIGH DYNAMIC (JTU-II)

This specification consists of pages i to ix and pages 1 through 71, inclusive.

Approved:

A handwritten signature in black ink, appearing to read "Donald Seifert", is written over a horizontal line.

By Direction

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1.0 SCOPE

1.1 Introduction

This specification establishes the performance, test, and acceptance requirements for the high dynamic version of the Joint Advanced Missile Instrumentation (JAMI) Time-Space Position Information (TSPI) Unit or JTU. The JTU consists of four primary internal components: (1) Global Positioning System (GPS) Sensor Unit (GSU); (2) Inertial Measurement Unit (IMU); (3) Data Formatter; (4) Power Distribution/Filter System. The high dynamic versions of the GSU and JTU are designated as “-II” versions; i.e., GSU-II and JTU-II. For simplicity, throughout this Specification the terms GSU and JTU refer to the high dynamic (-II) versions unless otherwise specifically noted.

1.2 Background

The JTU is intended for installation into high-dynamic missiles, weapon systems and targets. The JTU is designed to combine and process GPS satellite Coarse/Acquisition code from a GPS receiver, air vehicle dynamics from an IMU, and output the collected data in a standard format. The data is then sent to the host air vehicle telemetry system and transmitted to the JAMI Data Processor (JDP) which is the ground processing subsystem. The JDP processes the TM data from the JTU and provides resolved TSPI and/or other navigational or scoring data to the range users. Thus the airborne JTU combined with a ground processor will provide TSPI for missile tracking and a similar JAMI unit will enable target tracking to meet Navy/Air Force/Army range safety and missile test and evaluation requirements. This set of integrated JAMI units will also support vector scoring. Relaying the JTU information to the JAMI ground station will provide the ability to track airborne vehicles and score end game results in areas without standard radar or other “line-of-sight” tracking instrumentation.

1.3 Acquisition

This specification will be part of the acquisition documentation. “Government” and “Contractor” as referred to in this document means the Government procuring agency and the contractor/manufacturer respectively. The Contractor is expected to propose alternate approaches in achieving the requirements stated herein as well as test and/or verification methodologies that can be expected to achieve equivalent results in less time or with less cost. The Contractor is also invited to identify those requirements that are considered to be excessive in cost or not testable in a reasonable manner. Sections of this Specification refer to “examples” for discussion and alternate methodology in order to allow for developmental flexibility. The intent is to allow reasonable leeway to the contractor in the implementation of the design, fabrication, and verification requirements called out in this Specification while the performance requirements are met and verified. It is the intention of the Government to activate the intentions of this paragraph in subsequent acquisition documentation as deemed necessary at the time of the formal procurement. Any deviation from or addition to this specification shall be specifically noted in the acquisition documentation.

1.4 Design concept

1.4.1 General

The JTU is a data acquisition system that processes three types of data; GPS, IMU, and external events. RS 232 input capability is provided for configuration management. The GSU accepts external RF antenna input, which must be conditioned by an external filter/limiter/amplifier (FLA). The JTU can monitor and time tag three buffered, external event, discrete items for incorporation into its output data stream.

1.4.2 IMU Data

Signals from internal triaxially mounted accelerometers and rate sensors are conditioned and digitized as IMU data by an internal data acquisition system. Continuous IMU data is then combined with burst-mode GPS/event data and formatted for output by an internal processor.

1.4.3 Processing

The data formatter circuit card performs the function of a communications controller hub. This device collects, collates and formats the IMU, GPS and external event data. The formatter conditions the data as described in the TSPI Unit Message Structure (TUMS) format, monitors the mode selection inputs, and converts the output data to the software selected format for inclusion in the data stream.

1.4.4 Power conditioning

The JTU Power Distribution Module contains a line filter and converter that changes the 28 Vdc supply power to the lower voltages required by the other subsystems.

1.4.5 Output

The JTU provides the following format options for digital data output:

- a. 16-bit parallel port
- b. NRZ-L serial port
- c. RS-232 serial port

The data that is to be utilized during operations is sent to the external missile telemetry (TM) system for transmittal to the JAMI Data Processor (JDP) Ground Unit. The protocol of the TUMS is defined in the JAMI TUMS Digital Protocol Specification. The geographical track and position data is resolved in the JDP.

2.0 APPLICABLE DOCUMENTS

2.1 General

The documents listed in this section are specified in Sections 3, 4, and 5 of this specification. This section does not include documents cited in other sections of this specification or recommended for additional information or cited as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements documents cited in Sections 3, 4, and 5 of this specification, whether or not they are listed.

2.2 Government documents

2.2.1 Department of Defense specifications, standards and handbooks

The following specifications, standards, and handbooks form a part of this specification to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards and supplement thereto. Unless otherwise indicated, documents shall be of the issue in effect at the time of the solicitation.

STANDARDS

Federal

DOD-STD-1399/070	Interface Standard for Shipboard Systems Section 070, Part I DC Magnetic Field Environment (Metric)
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Military

MIL-STD-130	Identification, Marking of U.S. Military Property
MIL-STD-461E	Control of Electromagnetic Interference Characteristics of Subsystems and Equipment, Requirements for
MIL-STD-810F	Standards for Test Methods; Environmental Engineering Considerations and Laboratory Tests
MIL-STD-889	Dissimilar Metals
MIL-STD-1472	Human Engineering Design Criteria for Military Systems, Equipment and Facilities
MIL-STD-1686	Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)(Metric)

MIL-STD-7179	Finishes, Coatings, and Sealants for the Production of Aerospace Weapons Systems
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HANDBOOKS

MIL-HDBK-217	Reliability Prediction of Electronic Equipment
MIL-HDBK-263	Electrostatic Discharge Control Handbook for Protection of Electrical and Electronic Parts, Assemblies, and Equipment (Excluding Electrically Initiated Explosive Devices) (Metric)
MIL-HDBK-454	General Guidelines for Electronic Equipment
MIL-HDBK-781	Reliability Test Methods, Plans and Environments of Engineering Development, Qualification and Production
MIL-HDBK-46855	Human Engineering Guidelines for Military Systems, Equipment and Facilities

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Document Automation and Production Service (Building 4/D), 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

2.2.2 Other government documents, drawings, and publications

The following other Government documents, drawings, and publications (of the exact issue shown) form a part of this document to the extent specified herein. Unless otherwise specified, the issues are those cited in the solicitation. Documents not identified by specific revision or date shall be of the issue in effect in the solicitation (see 6.2).

DOCUMENTS

Naval Air Weapons Center Weapons Division
(Cage Code 12934)

NAWC-CH 3125	High Dynamic JAMI GPS Sensor Unit (GSU), Performance Specification
NAWC-CH 3132	JAMI TUMS Digital Protocol, Definitions Specification

Naval Sea Systems Command
(Cage Code 53711)

TE-000-AB-GTP-020 Environmental Stress Screening Requirements and Application
Manual for Navy Electronic Equipment

Cruise Missile Program (CMP)

3123AS1088 Fuel, JP-10

(Unless otherwise indicated, copies of other Government documents, drawings, and publications are available from the Program Executive Officer, Cruise Missiles and Joint Unmanned Aerial Vehicles, Patuxent River, MD 20670-1547.)

2.3 Non-government publications

The following non-government documents of the exact issue shown form a part of this specification to the extent specified herein. Documents not identified by specific revision or date shall be of the issue in effect in the solicitation.

SAE Aerospace Material Specifications:

SAE-AMS-STD-2175	Castings, Classification and Inspection of
SAE-AMS-A-21180	Aluminum-Alloy Castings, High Strength
AMS 5342 D	Steel Castings, Investment, Corrosion Resistant
AMS 5343 D	Steel Castings, Investment, Corrosion Resistant

(Application for copies of SAE Aerospace Material Specifications should be addressed to SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001)

Electronic Industries Alliance (EIA):

Standard RS-232	Interface Between Data Terminal and Data Equipment and Data Circuit Terminating Equipment Employing Serial Binary Data Interchange
Standard RS-422	Electrical Characteristics of Balanced Voltage Digital Integrated Circuits
JEDEC/JESD8-B	Interface Standard for Nominal 3V/3.3V Supply Digital Integrated Circuits

(Application for copies should be addressed to Electronic Industries Alliance, 2500 Wilson Blvd. Arlington, VA 22201 or copies may be found on website “www.jedec.org”)

(Non-Government standards and other publications are normally available from the organization that prepares or distributes the documents. These documents also may be available in or through libraries or other information services.)

2.4 Order of precedence

In the event of a conflict between the text of this specification and the references cited herein, the text of this specification takes precedence. Nothing in this specification, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3.0 REQUIREMENTS

3.1 Item definition

The Item described herein is a High Dynamic JAMI TSPI Unit assembly with the nomenclature of JTU-II; herein after referred to as the “JTU” or “Item”. It provides GPS satellite data and air vehicle dynamics to the vehicle TM system for transmission to a ground receiver. Connectors and ports described are part of the JTU unless indicated otherwise.

3.1.1 Interface definition

A functional and interface block diagram concept is shown in Figure 1. The JTU shall provide the basic interface functions shown here. Except as further specified herein, Figure 1 should not be interpreted as specific JTU design or interface requirements. See Appendix A for specific interface requirements.

3.1.1.1 GSU/JTU Interface

The GSU/JTU interface shall be a direct connect (card-to-card) type interface. The GSU J3 connector is defined in the GSU Specification NAWC-CH 3125. The design requires that the JTU provide the power required to the GSU. This interface as defined in the GSU Specification may be modified as necessary to accommodate a particular design requirement providing the performance requirements herein are met.

3.1.2 Input power

The Item shall be supplied with 28 Vdc power to the input connector. The Item shall operate as specified herein during the power conditions of this paragraph.

3.1.2.1 Steady-state voltages

The steady-state DC voltage supplied to the Item shall be not less than 20.0 Vdc, nor greater than 34.0 Vdc at the input connector.

3.1.2.2 Out-of-range voltage

The Item shall not be damaged and future performance shall not be degraded as a result of the application of steady-state input voltages of less than 20 Vdc or between 34 to 40 Vdc. Should out-of-range voltage cause malfunction, performance as specified herein is required within 3 seconds after the voltage is returned to the specified levels.

3.1.2.3 Power consumption

The power consumption of the Item under steady state conditions of 3.1.2.1 shall not exceed five (5) watts.

3.1.2.4 Spike voltage

The Item shall operate as prescribed herein without damage with the voltage spike characteristics of Figure 2 present at any of the 28 Vdc power pins of the J2 input connector.

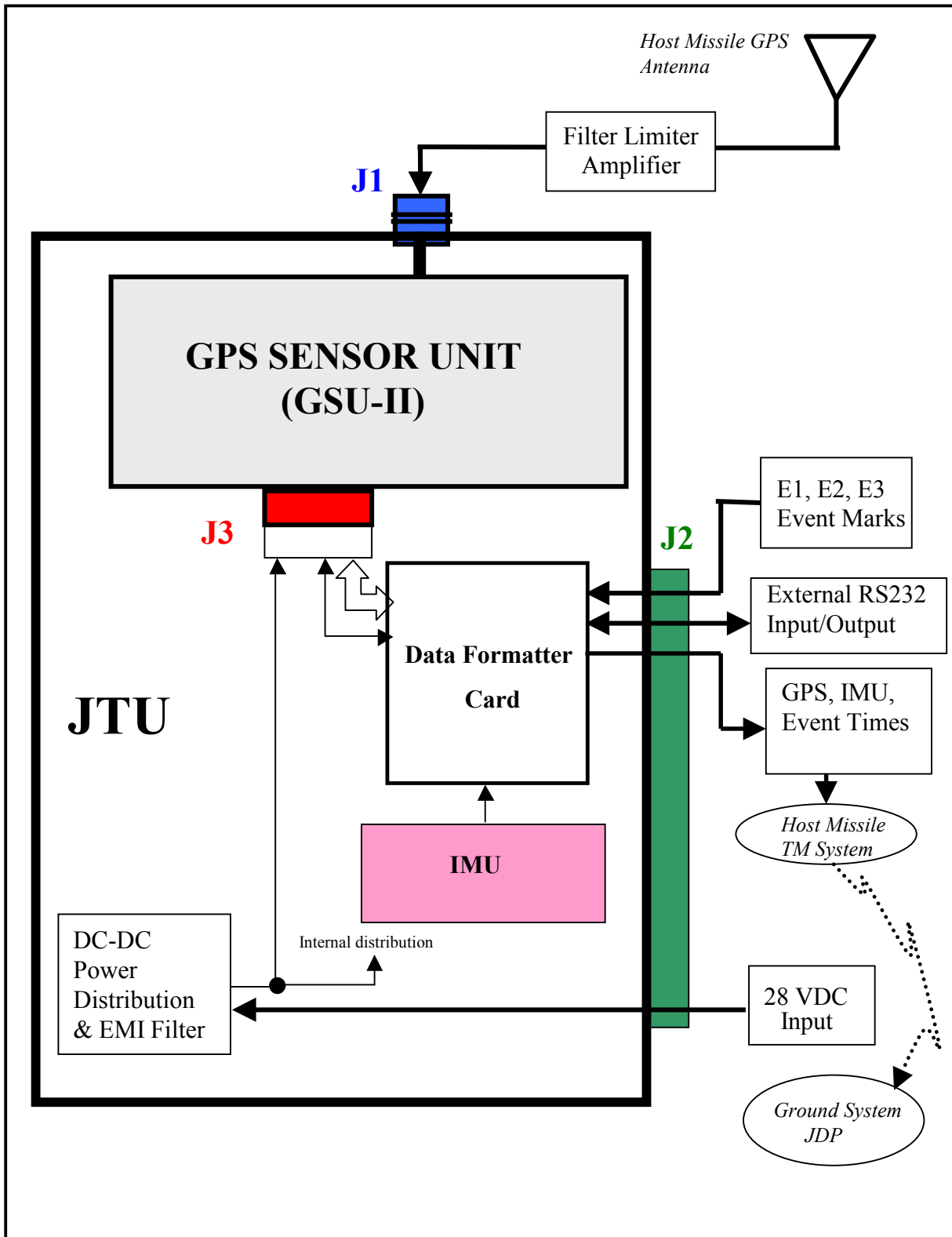
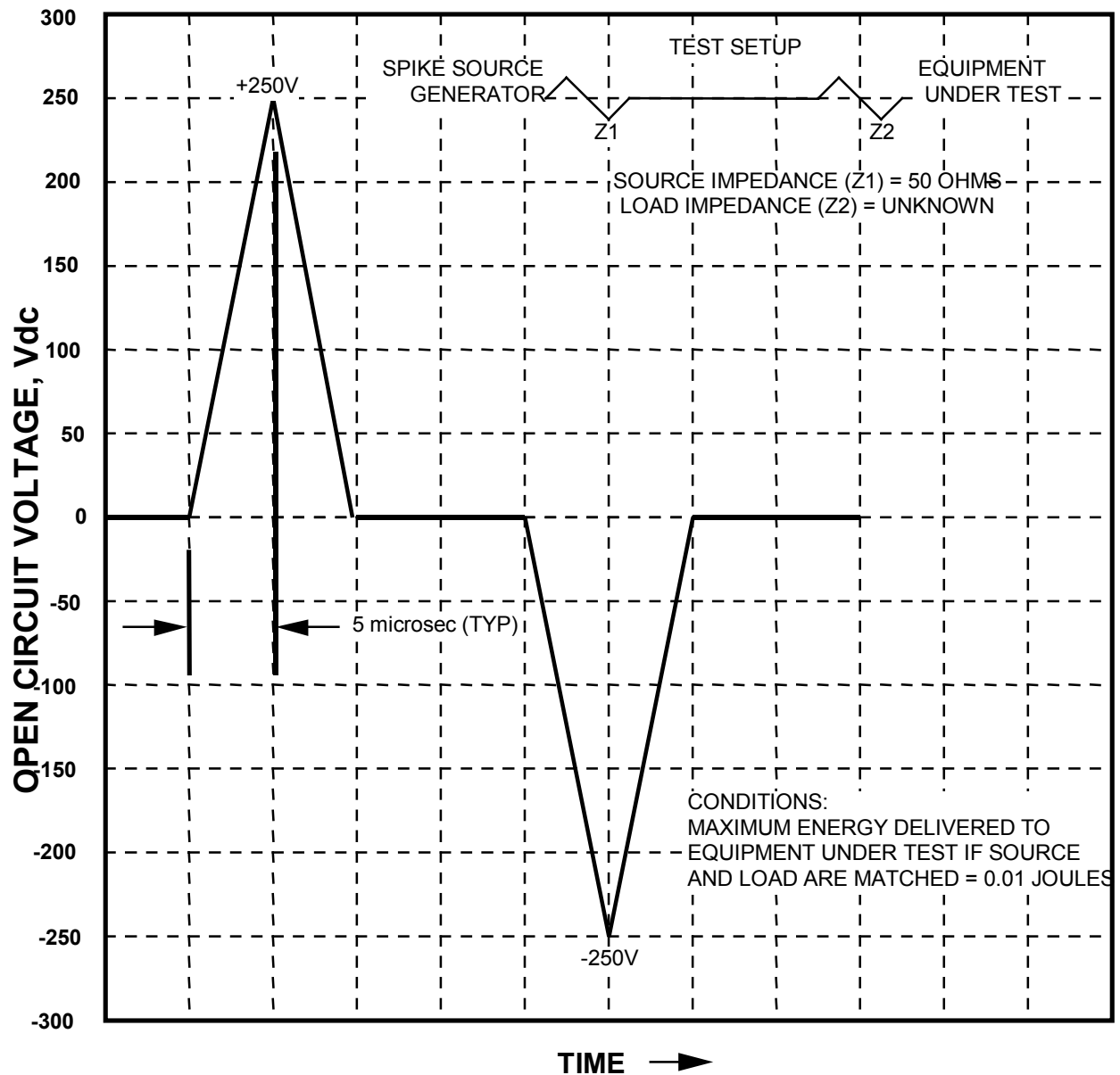


FIGURE 1. JTU Interface/Functional block diagram.



For power lines, spike voltage is ± 250 volts (as shown above)
superimposed on the nominal voltage specified in 3.1.2.1.

FIGURE 2. Spike voltages.

3.1.2.5 Step voltage characteristics

The Item shall withstand the step voltage application of power, such as from application by the contacts of a relay or switch. The rise-time of this voltage shall not be greater than 100 volts per microsecond.

3.1.2.6 Back-electromotive force (EMF)

The back-EMF voltage from the power input shall not exceed 70 Vdc when supplied from a representative type of missile/target power supply.

3.1.2.7 Short circuit protection

After exposure to an output short circuit on connector J2, the Item shall be automatically restored to operating performance within two seconds. A short circuit on an input connector pin shall not affect other inputs unless they are functionally related.

3.1.2.8 Polarity protection

The Item shall not be damaged when subjected to polarity reversal at the power input for up to one minute.

3.2 Characteristics

3.2.1 Performance

The item shall perform as specified herein within 25 seconds after being supplied power in accordance with 3.1.2. See 6.2.1 regarding operational “warm-up” time.

3.2.1.1 Flight environment

The Item shall meet all the operational performance requirements specified herein throughout this specified flight environment. This applies to all axes.

- a. Velocities up to 5,000 feet per second.
- b. Accelerations up to 50g.
- c. Jerk of 500g per second for a 0.1 second duration.

3.2.1.2 GPS Operation

The Item shall integrate with the GSU such that it will operate in accordance with the GSU Performance Specification NAWC-CH 3125. GPS measurement and performance accuracy shall be as specified in the GSU Specification. The GSU RF input line (GPS signal) requires an appropriate FLA matched to the vehicle antenna and wiring.

3.2.1.2.1 GPS Latency

Data latency for the JTU shall be defined as the time, after warm-up (see 6.2.1), between the time when the GPS L1 input is visible to the GPS RF antenna and the time when the TUMS message for that initial epoch is present at the output of the connector J2. The maximum allocation for this data latency shall be 125 ms.

3.2.1.3 Accuracy

At the JTU (system) level, the GPS-aided accuracy requirements shall be as specified in the GSU Specification for a signal with no jamming and operating at 50g acceleration.

3.2.1.4 Inertial Measurement Unit (IMU)

3.2.1.4.1 Operation

Each Item shall have an IMU subassembly that shall measure angular rates and linear accelerations for all three principle axes of an air vehicle. Each linear acceleration channel shall provide specified outputs for input accelerations up to ± 50 g's for each axis. Each angular rate sensor shall provide specified outputs for input rates up to ± 500 degrees/second. All specifications of this section refer to data after the analog to digital conversion.

3.2.1.4.2 IMU/JTU Orientation

The IMU shall have a fixed orientation relative to the JTU so that the JTU platform can be referenced to the proper aeronautical axis of the vehicle involved. This orientation shall be as shown in Figure 3.

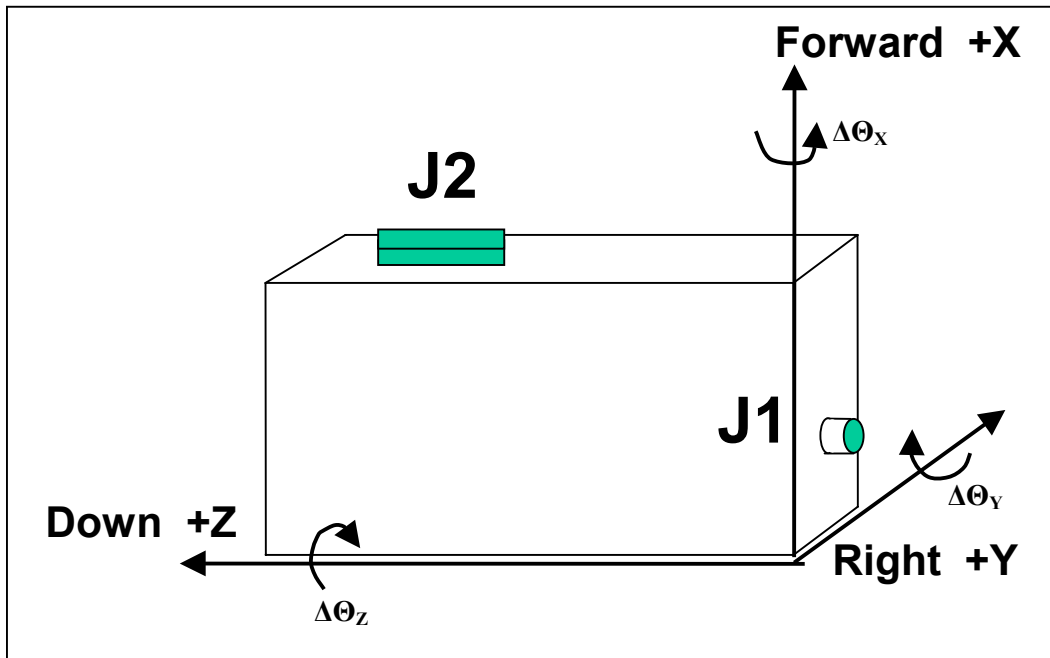


FIGURE 3. IMU/JTU Axis Orientation.

3.2.1.4.3 Requirements

3.2.1.4.3.1 Activation time

The IMU shall provide data meeting all performance requirements specified in this document within 20 seconds after being supplied power in accordance with 3.1.2. See 6.1.1.

3.2.1.4.3.2 Data

The IMU shall provide three-dimensional inertial specific force and angular rate data for eventual use in enhancing the GPS tracking solution. The data shall be in the form of accumulated incremental angular rates transformed to quaternions and accumulated incremental specific force (ΔV). The data shall be available in digital format to be accepted by a strobe signal from the data formatter as discussed in 3.2.1.5.

3.2.1.4.3.3 Acceleration and angular rates

The IMU shall be capable of measuring and outputting accelerations and angular rates in accordance with the data parameters of Table I.

3.2.1.4.3.4 Accuracy

The accuracy of the IMU shall support the requirements given in Table I. Wide band noise refers to the high frequency random component of the specific force and platform rate measurements. RMS bias refers to the root mean square of all bias terms. The conditioned IMU sensor outputs shall be accurate to better than 0.01%. The accuracy shall include effects of non-linearity and temperature variations. Conditioning may be done during digital processing as referenced in the Data Formatter section.

TABLE I. IMU Data Requirements

Motion →	JTU Platform Rotation	JTU Platform Acceleration
Requirement ↓		
Measurement Range	+/- 500 deg/sec = +/- 8.7 mrad @ 1000 Hz	+/- 40g = +/- 1.6 ft/sec @ 1000 Hz
Digital Resolution*	14 Bits	14 Bits
Wideband Noise	0.05 deg/sec/√Hz	2.5 mg/√Hz
RMS Bias	0.3 deg/hr	10 mg
Sensor Misalignment	2 deg	2 deg
Scale Factor Error	0.1%	0.1%
Scale Factor Asymmetry	0.1%	0.002%
g-sensitivity	0.2 deg/sec/g	N/A
Turn-on Bias	300 deg/hr	17.5 mg
Time Varying Bias	180 deg/hr	N/A
Frequency Response	200 Hz	200 Hz

* Per measurement at 1000Hz

3.2.1.4.3.4.1 Error model

In addition to meeting the overall accuracy requirements, the contractor shall provide a detailed error model of the IMU in sufficient detail to support covariance and simulation analysis. For accelerometers, this information shall include turn-on bias, time-varying bias, wideband noise, scale factor uncertainty, scale factor asymmetry, non-orthogonal input axis, g-sensitive drift, g²-sensitive drift, and frequency response. For gyros, this information shall include turn-on bias, time-varying bias, wideband noise, scale factor uncertainty, scale factor asymmetry, non-orthogonal input axis, accelerometer-to-gyro misalignments, and frequency response.

3.2.1.4.3.5 Resolution

The resolution of the data output by the IMU shall be in accordance with Table I. This resolution as defined shall include all the processes involved in generating the data including the basic sensor resolution and the encoding resolution of the IMU digital output data.

3.2.1.4.3.6 Latency

The IMU component of the latency of the ΔV and $\Delta\theta$ shall be 10 μ s or less. This latency shall be the sum of the latency of the data at the time it is loaded into the output buffer and the time delay in transmitting the data on the interface bus after a transmit request is received.

3.2.1.4.3.7 Anti-Aliasing

The Anti-Aliasing low pass (-3dB) filter band width shall be 200 Hz \pm 10Hz.

3.2.1.4.3.8. Angular rate and acceleration sensors alignment

IMU performance requirements for platform axis angular rates and platform axis accelerations shall be referenced to the IMU axis/JTU orientation as shown in Figure 3. The principal axis of the inertial system shall be aligned with the principal axis of the platform (JTU) within 15 arcseconds.

3.2.1.5 Data Formatter

3.2.1.5.1 Functional requirements

The Data Formatter shall provide the following capabilities. The design parameters that must be specified to meet integration requirements are covered in the following paragraphs.

- a. Provide a minimum of 32 bits of resolution for data processing.
- b. Sample the GSU digital data, buffer and hold as necessary.
- c. Sample the IMU analog data, convert to digital, process and buffer as necessary.
- d. Provide the computational capability as described in Appendix C.
- e. Condition the external event markers.
- f. Correlate the data with the GSU clock.
- g. Provide status bits that represent the health of various JTU functions.
- h. Format the GSU and IMU data into the message format as described in this paragraph.
- i. Output data as described in TUMS Specification.
- j. Provide provisions for RS-232 input signals for configuration purposes.
- k. Provide for a GSU mode command signal via the GSU/JTU connector (J3).
- l. Provide a mechanism for programming a unique serial number for each unit into the formatter card logic and outputting this serial number in the "Status Word" of the TUMS Source Data Field as required in the TUMS Specification.

3.2.1.5.2 External Data Processing

The Data Formatter shall process and control the following input and output data via the J2 connector. The J2 configuration is covered in Appendix A.

3.2.1.5.2.1 Outputs

- a. One (1) pulse-per-epoch (1 PPE) which is the GPS data measurement rate.
- b. Variable frequency (VARF) signal which is the sample rate of the IMU data.
- c. A 16 bit parallel data port (D00 through D15) to output TUMS data to a telemetry encoder input using the handshaking outlined in paragraph A.2.2.2.4. D15 is defined to be the most significant bit. This data shall be tri-stated LVTTTL signals.
- d. NRZ-L output that contains TUMS data as a serial TTL signal at a rates of up to 230 Kbits/sec. This NRZ-L data stream shall be at a fixed data rate that can be programmed. The default rate shall be 230 Kbits/sec.
- e. RS-232 shall be used for configuration and testing purposes as well as outputting TUMS at rates up to 230 Kbaud. The RS-232 output of TUMS may be used in support of a packet telemetry architecture.
- f. Status bits that can drive LED's to provide indications as to the health of the JTU.

3.2.1.5.2.2 Inputs

- a. Three external discrete events (EVENT1, EVENT2 AND EVENT3) which are RS-422 differential inputs.
- b. RS-232 serial input to be used for testing and configuring the JTU.
- c. +28 VDC power input. A MIL-STD-461C CE03-rated EMI filter internally filters this power.

3.2.1.5.2.3 Event markers

The event markers are external differential inputs from the J2 connector. These inputs shall be conditioned to the requirements of the GSU Specification and passed to the GSU. These markers are correlated to the GPS data in the GSU and the results are contained in the GSU data stream.

3.2.1.5.2.4 Signal levels

- a. LVTTTL signals are described in JEDEC/JESD8-B.
- b. The BIT outputs must be able to drive LED's at 10 ma.
- c. Differential event input levels shall be in accordance with RS-422.

3.2.1.5.3 Parallel data (16 bit) transfer protocol

3.2.1.5.3.1 Block transfer mode

The block transfer mode transfers a large block of TUMS data to the encoder. The first word of the block to be sent shall be a word count of the number of 16 bit words that are in the block of data that is to be transferred. This word counter shall be ignored at the decommutator side and has no effect on the content of the TUMS data. For this mode the parallel data output shall have the handshaking procedures described below and shown in Figure 4.

- a. MODE_SEL (input) - The MODE_SEL line shall be set low to select the Block Transfer Mode.
- b. CHIP_SEL (input) - The CHIP_SEL signal into the JTU shall go low indicating the encoder is ready to accept a block of data. The BLK_XFR line from the JTU shall then go low indicating that a valid data block is ready to be transferred. The CHIP_SEL signal then shall toggle after each data word is accepted and the encoder is ready for the next word.
- c. BLK_XFR (output) - This signal shall go low after receiving a request for data from the encoder, CHIP_SEL set low, and valid data is buffered and ready to be transferred to the encoder. Once all the buffered data is transferred, BLK_XFR line shall go high.
- d. DAT_STB (output) - The falling edge of this signal shall indicate that the data is stable and is ready to be read by the encoder. The pulse width shall be between 40 and 60 ns.

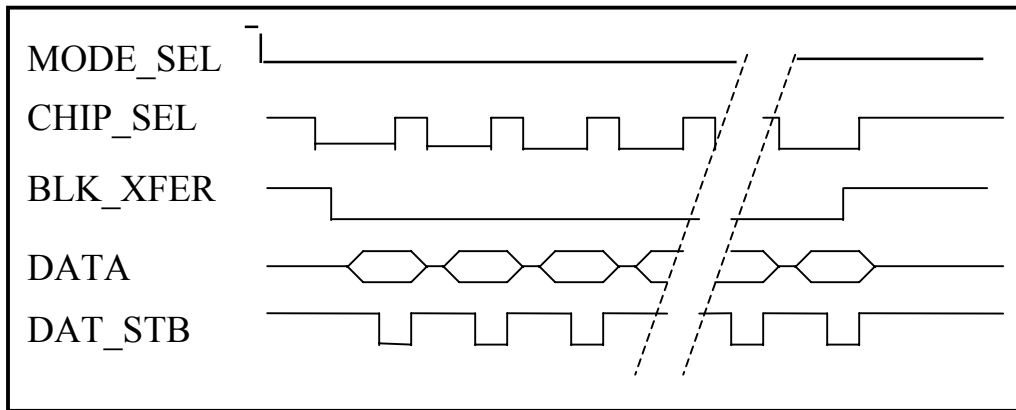


FIGURE 4. Block Transfer Mode Handshaking.

3.2.1.5.3.2 Free running mode

The free running mode transfers the TUMS data to the encoder as soon as it is available. For this mode the parallel data output shall have the following handshaking procedures described below and shown in Figure 5.

- MODE_SEL (input) - The MODE_SEL line set high shall select the Free Running Mode.
- CHIP_SEL (input) - The CHIP_SEL signal into the JTU shall go low indicating the encoder is ready to accept a word. The BLK_XFR line from the JTU shall then go low if the data word is valid. When the encoder has read the data word the CHIP_SEL line shall then be set high.
- BLK_XFR(Output) - This signal shall go low after receiving a request for data from the encoder, CHIP_SEL going low, and valid data is present and ready to be read by the encoder. After CHIP_SEL goes high, BLK_XFR line shall go high.
- DAT_STB (output) - The falling edge of this signal shall indicate that the data is stable and is ready to be read by the encoder. The pulse width shall be between 40 and 60 ns.

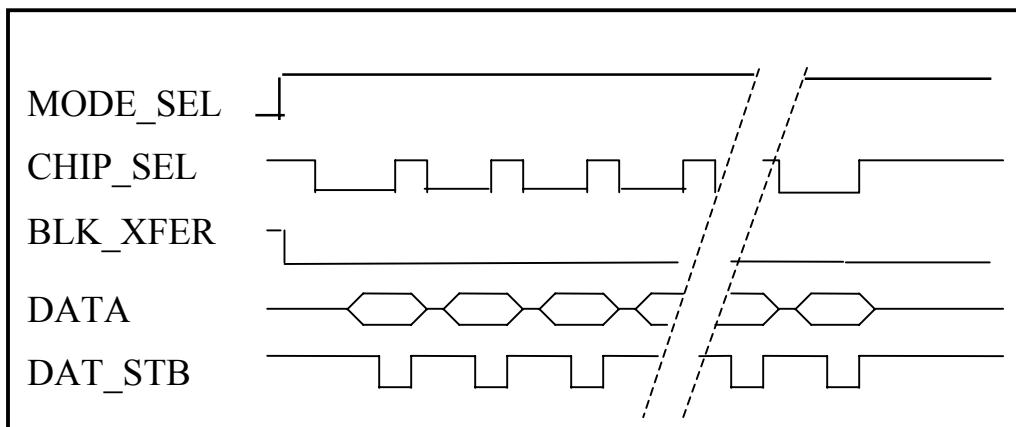


FIGURE 5. Free Running Mode Handshaking.

3.2.1.5.4 Time and sampling relationships

The GSU shall provide the basic timing for the JTU formatter card. The GSU will provide two pulse strobes: one for the GSU/JTU data output cycle and one for the raw IMU data sampling cycle. These are referred to respectively as the “epoch pulse strobe” (EPS) or “pulse per epoch” (PPE) and the “variable frequency output” (VARF). The leading edge of these time strobes shall be synchronized with the VARF rate being an integer multiple of the basic EPS (GSU) rate. For the purposes of examples in this Specification, the IMU raw data sampling rate (VARF) will be considered to be 1000 Hz and the relationships discussed will be based on this rate. Several possible rate scenarios are covered in Table II as examples. These example rates in this specification are for discussion and illustration only and are not requirements. While several of the values discussed herein may be selectable, there are fixed integer relationships that are required for proper data formatting.

TABLE II. Possible Data Rate Scenarios

Nomenclature	Must be...	TUMS Type I-10-0-1000-5	TUMS Type I-10-0-1000-10	TUMS Type II-15.625-0-1000-4	TUMS Type II-15.625-0-1000-8
GPS Cycle Time - T_G (sec)		0.1	0.1	0.064	0.064
GPS Message Frequency - $1/T_G$ (Hz)	≥ 10 Hz	10	10	15.625	15.625
GPS/IMU Clock Multiplier $N_I \cdot N_G$	Integer	100	100	64	64
Raw IMU Cycle Time - T_R (sec)		0.001	0.001	0.001	0.001
Raw IMU Sample Frequency $1/T_R$ (Hz)	~ 1 KHz	1000	1000	1000	1000
Integrator Count (n^{th} cycle) N_I	Integer	5	10	4	8
IMU Accumulation Cycle Time T_I (sec)		0.005	0.010	0.004	0.008
IMU Accumulation Frequency (Hz)		200	100	250	125
TUMS Message Frequency - $1/T_G$ (Hz)		10	10	15.625	15.625
IMU Samples Per TUMS Message - N_G	Integer	20	10	16	8
TUMS Envelope Size (bytes)		10	10	10	10
MATM Message Size (bytes)		18	18	18	18
MACM or GSU Message w/ 12 sat (bytes)		303	303	648	648
IMU Size (bytes)		428	218	344	176
Approx. TUMS Size (bytes)		759	549	992	824
Minimum TM rate (bits/sec)		60720	43920	124000	103000
25% Oversampling TM Clock (bits/sec)		75900	54900	155000	128750

3.2.1.5.5 Inputs

3.2.1.5.5.1 GSU Message

The GSU message will contain the GPS data in either of two formats depending on the type of GSU installed. These are referred to as TUMS Type I or TUMS Type II. The Type I message contains processed GPS data and the Type II contains raw satellite data in a contractor specified format. The formatter card does not further process this GSU data and therefore, the particular Type of message is of no consequence to the formatter card functionality. The formatter card shall sample and hold this data until the IMU data is ready for inclusion. The formatter shall then prepare the TUMS packet message and output the TUMS message in the format described in the JAMI TUMS document.

3.2.1.5.5.2 GSU Sample rate (EPS)

The time between GSU data output (period), referred to as a GPS epoch, shall be T_G seconds which provides a sample rate of $1/T_G$. This strobe is referred to as the EPS or the Pulse Per Epoch (PPE). All JTU data sampling shall be synchronized to this strobe and all data processing and formatting must be completed during the period, T_G , of this strobe. This value shall be selectable between 10 – 20 Hz. For example purposes of this document T_G shall be 0.064 seconds for an update rate of 15.625 Hz.

3.2.1.5.5.3 IMU Sample rate (VARF) ($1/T_R$)

The IMU raw analog data sample rate shall be $1/T_R$ Hz with a period of T_R seconds. This value shall be selectable as an integer number of pulses per epoch. For example purposes of this document T_R shall be 0.001 seconds for an update rate of 1000 Hz. The IMU analog data shall be read simultaneously from all six IMU sensors, converted to digital format and buffered for output every 0.001 seconds.

3.2.1.5.5.4 IMU Integration factor (N_I)

The high rate digital IMU data shall be integrated over the integration factor (N_I) number of samples. N_I must be an integer between 1 and 10, and must be an integer divisor of the number of raw IMU samples taken in an IMU integration period. Integration is defined as the accumulation of a set (N) of ΔV and $\Delta\theta$ samples. This value shall be selectable and shall be preloaded into the logic. The example value for N_I is 4.

3.2.1.5.5.5 IMU Accumulation factor (N_G)

The integrated digital IMU data shall then be accumulated over a number (N_G) of accumulated samples per epoch. This N_G must have an integer relationship between N_I and EPS ($1/T_G$) and is dependent on these values. This value shall be selectable, subject to the relationship discussed, and shall be preloaded into the logic. See Table II for examples.

3.2.1.5.6. JTU data message structure (TUMS)

The JTU shall format the data output as required in the TUMS Specification. Those items required for an understanding of the JTU operation are included herein. The detailed TUMS requirements are covered in the TUMS Specification. The TUMS message structure shall be based on the packet structure of IRIG 106-01 Part II.

3.2.1.5.6.1 Source data field

The JTU navigation data is contained in the source data field of the TUMS Packet. The Source Data field starts with a status and word and contains one epoch of data from the GSU and the associated processed IMU data for the present GSU epoch. An epoch is defined as a GPS cyclic measurement with a period between 0.1 and 0.05 seconds (10 to 20 Hz). During the epoch period the IMU sensors are sampled and processed. The period is determined by the configuration of the GSU installed. Table III shows the overall structure of the Source Data Packet. The number in parenthesis indicates the number of bytes needed for that data set.

TABLE III. Source Data Packet Structure

Source Data Field			
Status Word(2)	GSU Data(Variable)	IMU Data(Variable)	CKSUM(1)

3.2.1.5.6.2 Status word

The status word contains the TUMS message type identifier, five status bits that contain the results of built in tests that report the health status of certain sensors, and the JTU unit serial number. The word definition is shown in Table IV with the functional description of the Bits in the following paragraphs.

TABLE IV. Status Word

Bit	15	14	13	12	11	10	9	8,7,6,5,4,3,2,1	0
Function	Type	Reset	GSU	Fail	Dynamic	Static	<<<Unit serial number>>>>		
							MSB		LSB

3.2.1.5.6.2.1 Unit ID Bit (9 - 0)

This series contains the JTU unit serial number with bit 9 as the most significant bit (MSB) and bit 0 as the least significant bit (LSB).

3.2.1.5.6.2.2 Static Bit (10)

This bit is set to "1" when all the IMU sensor outputs are equivalent to a static vehicle. Otherwise it shall be set to "0."

3.2.1.5.6.2.3 Dynamic Bit (11)

This bit is set to "1" when dynamic activity is detected on any IMU sensor. Otherwise it shall be set to "0."

3.2.1.5.6.2.4 Fail Bit (12)

This bit is set to "1" if any of the sensor outputs are near the rails or if the DC bias of the sensors is not in the expected range. Otherwise it shall be set to "0."

3.2.1.5.6.2.5 GSU Bit (13)

This bit provides information on the performance of the GSU. Upon power up the bit will toggle with a period of 2 seconds. This will indicate that GSU is powered and searching for satellite vehicles. When satellites have been acquired the bit will then toggle on for 1 second then off for 0.5 seconds followed by the bit toggling of 1-second period for each satellite tracked. Once all satellites have been counted, the bit will toggle off for 1 second and the reporting cycle will start over.

3.2.1.5.6.2.6 Reset Bit (14)

This bit shall be set for a period of one second after a processor reset has occurred.

3.2.1.5.6.2.7 Type Bit (15)

This bit shall be set to 1 for a TUMS Type I message and to 0 for a TUMS Type II message.

3.2.1.5.6.3 GSU Data

The GSU data shall be formatted as Type I or II in accordance with the TUMS Specification.

3.2.1.5.6.4 IMU Data structure

The GSU EPS strobe firing (t_0) triggers the formatter card to sample and hold that epoch of GSU data. At the same time, t_0 , the formatter card starts sampling the raw IMU data at the higher rate of $1/T_R$ in response to the synchronized VARF strobe. The six IMU sensors shall be sampled simultaneously at this raw IMU measurement rate ($1/T_R$). Each set of IMU data shall be processed and formatted as discussed in the following paragraphs. The formatted IMU data shall be appended to the end of the GSU data and will contain the samples from each sensor in the IMU that were processed during the GSU epoch. Each GSU epoch shall result in one TUMS message packet. Figure 6 shows these timing relationships. The values in () indicate the values for the example rates. The time of the first IMU sample shall be the time of the GSU message for that epoch. Table V shows the IMU message structure for the accumulated data. The last column of Table V indicates the time the IMU sample was made relative to the GSU epoch start time (t_0). The number in parenthesis is the number of bytes for that parameter. The specifics of the required message structure are covered in the JAMI TUMS document.

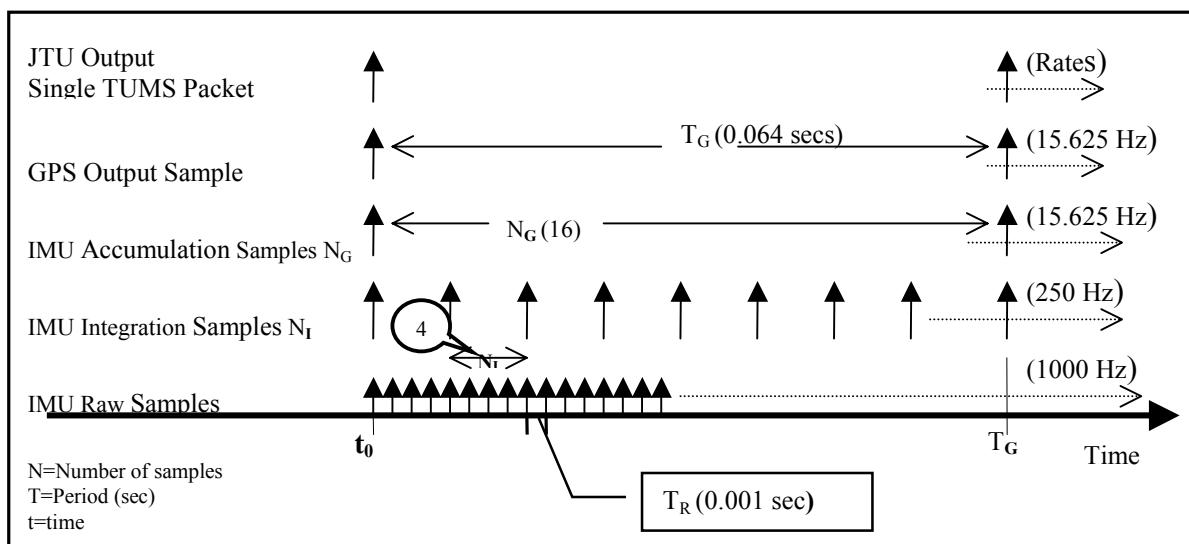


FIGURE 6. Timing Relationships.

TABLE V. IMU Data structure

Header (3)	Counter (2)						$T=t_0 + n \cdot T_I$ ($n=0$ to N_G)
$\Sigma \Delta V_x(3)$	$\Sigma \Delta V_y(3)$	$\Sigma \Delta V_z(3)$	$\Sigma Q_0(3)$	$\Sigma Q_x(3)$	$\Sigma Q_y(3)$	$\Sigma Q_z(3)$	$T=t_0$
$\Sigma \Delta V_x(3)$	$\Sigma \Delta V_y(3)$	$\Sigma \Delta V_z(3)$	$\Sigma Q_0(3)$	$\Sigma Q_x(3)$	$\Sigma Q_y(3)$	$\Sigma Q_z(3)$	$T= t_0 + 1 \cdot T_I$
$\Sigma \Delta V_x(3)$	$\Sigma \Delta V_y(3)$	$\Sigma \Delta V_z(3)$	$\Sigma Q_0(3)$	$\Sigma Q_x(3)$	$\Sigma Q_y(3)$	$\Sigma Q_z(3)$	$T= t_0 + 2 \cdot T_I$
$\Sigma \Delta V_x(3)$	$\Sigma \Delta V_y(3)$	$\Sigma \Delta V_z(3)$	$\Sigma Q_0(3)$	$\Sigma Q_x(3)$	$\Sigma Q_y(3)$	$\Sigma Q_z(3)$	$T= t_0 + 3 \cdot T_I$
							.
							.
$\Sigma \Delta V_x(3)$	$\Sigma \Delta V_y(3)$	$\Sigma \Delta V_z(3)$	$\Sigma Q_0(3)$	$\Sigma Q_x(3)$	$\Sigma Q_y(3)$	$\Sigma Q_z(3)$	$T= t_0 + N_G \cdot T_I$
Check Sum(1)							

Key: T = Accumulation time stamp
 t_0 = Epoch begin time
 T_I = Integration period (secs) ($N_I \cdot T_R$)
 N_G = Number of accumulation samples for each epoch period
(x) = (bytes)

3.2.1.5.6.4.1 Header

The Header shall contain the ASCII characters "IMU".

3.2.1.5.6.4.2 Counter

This shall be a two-byte word containing the number of bytes contained in the IMU message including the header and ending with the status byte.

3.2.1.5.6.4.3 Accumulated data

Contains the data formatted as described in 3.2.1.5.5.

3.2.1.5.6.4.4 IMU Checksum

The last parameter of the IMU message shall be a one-byte checksum starting at the first bit after the IMU header. The checksum shall be calculated using XOR.

3.2.1.5.6.5 TUMS Data rate

The data rate of TUMS message will be a combination of the minimum rates needed for the GSU data and the IMU data. Table II shows examples of various data rate scenarios for different sample rates. The sample rates quoted herein are for discussion only and are not a requirement.

3.2.1.5.6.6 TUMS Nomenclature

Table II shows a scheme of applying a nomenclature to different types of TUMS message structures as a means of identifying the message structure to the JDP. The TUMS format will vary depending on the GSU, sample rates, etc. but will be fixed for a given set of hardware. The JTU shall contain a unit nomenclature alphanumeric series on the unit identification label that shall identify the structure of the TUMS message and thereby define the configuration of the particular unit. This nomenclature shall be composed as follows:

TUMS Type – GSU Rate – IMU Rate – Integration Factor (N)

For example, a TUMS packet that uses a MACM GSU message at a rate of 10 Hz, has an IMU measurement rate of 1000 Hz and a factor of 5 for the IMU integration, the nomenclature would be:

“I-10-1000-5”

This nomenclature will be input to the JDP “Personality Module” which will allow the JDP to properly process the TUMS message.

3.2.1.5.7 IMU Data processing

Each set of raw IMU sensor data shall be processed through an integration and an accumulation process. The rate sensor data shall also be processed through a quaternion axis transformation process. The resulting data structure shall be as shown in Table III.

3.2.1.5.7.1 IMU Calibration factors

The IMU sensor outputs shall be corrected for temperature variations, scale factors and offset errors if necessary to maintain a total processing accuracy to within 0.01% of full scale for bias nulls and 0.1% of full scale for scale factors.

3.2.1.5.7.2 Accumulated delta velocities

The acceleration data in the x, y and z directions shall be sampled at the raw IMU rate ($1/T_R$). Each sample shall be multiplied by T_R seconds (IMU sample period) to produce a delta velocity and then integrated over N_I samples. This integrated delta velocity data shall be converted into engineering units of mm/sec and the calibration factors shall then be applied. This calibrated delta velocity shall then be summed to the previous accumulated delta velocity to produce the new accumulated delta velocity for each direction ($\sum \Delta V_x$, $\sum \Delta V_y$, $\sum \Delta V_z$). The output for each direction shall be a 3-byte binary 2's complement number with the units of tenths of millimeters per second.

3.2.1.5.7.3 Accumulated Quaternion values

The angular rate data for each axis shall be sampled at the raw IMU rate ($1/T_R$) and then integrated over N_I samples. This integrated rate data shall be converted into engineering units and the calibration factors shall then be applied. The three sets of calibrated data are then processed through an attitude reference quaternion that produces a quaternion scalar (Q_0) and three vector components (Q_x, Q_y, Q_z). Each quaternion result shall then be multiplied by 2^{23} to provide an integer value with the proper resolution. Each of these four sets of processed data shall be added to the previous accumulated quaternion values to produce four new accumulated values ($\sum Q_0, \sum Q_x, \sum Q_y, \sum Q_z$). The output shall be a 3-byte unitless integer for each accumulated data sample.

3.2.1.5.7.4 Computational requirements

The computational requirements for the accumulation processing discussed herein are contained in Appendix C. The computational resolution shall be a minimum of 32 bits.

3.2.1.5.8 Failure monitoring

The Data Formatter shall provide hardware and/or self reliant software monitors that detect at least 95% of hardware failures. These hardware/software provisions and monitors shall operate periodically during normal operations without disrupting inertial outputs.

3.2.1.6 Erratic performance

At no time during its operation shall the Item exhibit abnormal behavior or erratic performance, even though such performance is within the limits of performance specified herein.

3.2.2 Physical characteristics

3.2.2.1 Weight

The weight of the Item shall not exceed 1.2 pounds.

3.2.2.2 Envelope dimensions

The envelope dimensions and general arrangement of the Item shall be as shown in Appendix B.

3.2.2.3 Structural integrity

The Item shall have no degradation in performance following exposure to all combinations of environments specified herein.

3.2.2.3.1 Durability

The Item shall provide the strength and durability required to satisfy the life and performance requirements specified herein for all structural members.

3.2.2.3.2 Resonance

The lowest resonant frequency of the Item shall be greater than or equal to 400 Hz.

3.2.2.4 Strength and rigidity

The Item shall have a margin of safety for the specified design requirements. The Item shall be designed to prevent yielding at limit load and to prevent failure at ultimate load. The limit load factor of safety shall be 1.0 and the ultimate load factor of safety shall be 1.5.

3.2.3 Reliability

The reliability of the Item shall be as specified herein for the life cycle conditions provided in the Table VI below and the applicable environmental conditions specified herein.

TABLE VI. Life cycle conditions

Situation/Event	Maximum Accumulation
Storage/Transportation	10 years
Test range/handling/testing	10 hours
Captive carriage (operating)	50 hours
Free flight (operating)	20 minutes
Catapulted launch and arrested landing	6 each total

3.2.3.1 Mean flight hours between failure

The predicted mean flight hours between failure (MFHBF) shall be no less than the following:

- a. Captive-carriage MFHBF of 2,611 hours.
- b. Launch MFHBF of 1,660 hours.
- c. Free flight MFHBF of 4,241 hours.

3.2.3.2 Operational reliability

The Item shall be capable of operating continuously throughout a single mission that consists of a two hours duration captive carry and a 1,200 seconds duration free flight. The probability that the Item functions as specified herein throughout a single mission shall be no less than 0.99 at a confidence level of not less than 0.95.

3.2.3.3 Operating life.

The operating life shall be no less than 100 hours. Operating life shall be the cumulative time during which power is applied in all phases of testing, installation, and operation during captive carriage and flight.

3.2.4 Maintenance

3.2.4.1 Scheduled maintenance

The design shall require no scheduled maintenance, adjustment, or calibration during the useful life other than mission set-up downloads and a Go/No-Go test at the Round Level.

3.2.4.2 Maintainability

The Item shall not be supported as a repairable item, therefore, the design shall not be required to accommodate the replacement of hardware parts. The Item shall perform as specified herein after 10 years of storage when packaged in accordance with Section 5.

3.2.5 Environmental conditions

The Item shall operate as specified herein during and after exposure to the environmental conditions specified herein. Reliability analyses shall utilize these environmental conditions for the appropriate life times specified. The shock, vibration and acceleration environments shall apply to each axis to allow for any possible mounting orientation. The figures and tables related to this paragraph are grouped at the end of this complete paragraph.

3.2.5.1 Non-operating environmental conditions

The Item shall meet the requirements specified herein and suffer no reliability or operational degradation after exposure to any combination of the non-operating environments specified herein.

3.2.5.1.1 Low temperature

The Item shall maintain structural integrity and operate as specified herein after exposure to a case temperature of -54°C (-65°F) for a minimum duration of 72 hours.

3.2.5.1.2 Hot-Dry temperature cycling

The Item shall maintain structural integrity and operate as specified herein after exposure to seven consecutive diurnal cycles between 35°C (95°F) and 85°C (185°F) as shown in Table VII.

3.2.5.1.3 Shock - transit drop

The Item, when packaged as it would be for shipment, shall maintain structural integrity and operate as specified herein after being subjected to the transit drop shock test in MIL-STD-810F, Method 516, Procedure IV.

3.2.5.1.4 Transportation vibration

The Item, when packaged as it would be for shipment, shall maintain structural integrity and operate as specified herein after being subjected to the random vibration spectrum shown in Figure 7.

3.2.5.1.5 Handling shock

The Item shall maintain its structural integrity and operate as specified herein after being subjected to the shock spectrum shown in Figure 8.

3.2.5.2 Operating environmental conditions

The Item shall meet the performance requirements specified herein and suffer no reliability or operational degradation during and after exposure to any probable combination of the operating environments specified herein.

3.2.5.2.1 Low temperature

The Item shall operate as specified herein during and after exposure to a mounting surface temperature of -40° C (-40° F) for a duration of 2 hours. Each surface shall be considered a mounting surface unless a specific surface would make an unreasonable mounting choice.

3.2.5.2.2 High temperature

The Item shall operate as specified herein during and after exposure to a mounting surface temperature of 85°C (185° F) for a duration of not less than 2 hours. Each surface shall be considered a mounting surface unless a specific surface would make an unreasonable mounting choice.

3.2.5.2.3 Maximum pressure

The Item shall operate as specified herein during and after exposure to a pressure of 30.0 psia.

3.2.5.2.4 Altitude

The Item shall operate as specified herein during and after exposure to altitudes of sea level to 100,000 feet. The dwell time at 100,000 feet shall be 1 hour during which time the temperature extremes of 3.2.5.2.1 and 3.2.5.2.2 shall be applied in an appropriate cycle.

3.2.5.2.5 Pressure rate of change

The Item shall maintain structural integrity and operate as specified herein after exposure to pressure change rates equivalent to 4,000 ft/sec in ascent and 4,500 ft/sec in descent.

3.2.5.2.6 Relative humidity

The Item shall operate as specified herein during and after exposure to relative humidity of 100 percent using MIL-STD-810F, Method 507.3, Procedure III.

3.2.5.2.7 Acceleration

The JTU shall operate continuously, while being exposed to accelerations of up to plus and minus 50g constant acceleration in all axes for 5 minutes.

3.2.5.2.8 Composite vibration

The Item shall operate as specified herein during and after exposure to the vibration spectra shown in Figures 9, 10 and 11.

3.2.5.2.9 Composite flight shock

The Item shall operate as specified herein during and after exposure to the shock spectrum shown in Figure 12. If the Item operation is disrupted by the shock, the Item shall recover within one (1) second after the shock is applied.

3.2.5.2.10 Explosive atmosphere

The Item shall be capable of exposure to an explosive atmosphere without initiating the explosive atmosphere or affecting the vehicle performance in any way.

3.2.5.3 Electromagnetic environment

This requirement shall encompass both electromagnetic compatibility (EMC) and electromagnetic interference (EMI). When installed in the weapons system the Item shall cause no degradation in performance of the weapons system due to the electromagnetic properties of the Item when operating. The Item shall be capable of operating normally in accordance with the requirements herein, during and after exposure to the electromagnetic environments specified in this paragraph. The Item, to include input power leads and antenna cabling and connectors, shall meet the requirements of MIL-STD-461E for the interference and susceptibility requirements listed in Table VIII.

3.2.5.3.1 Magnetic fields

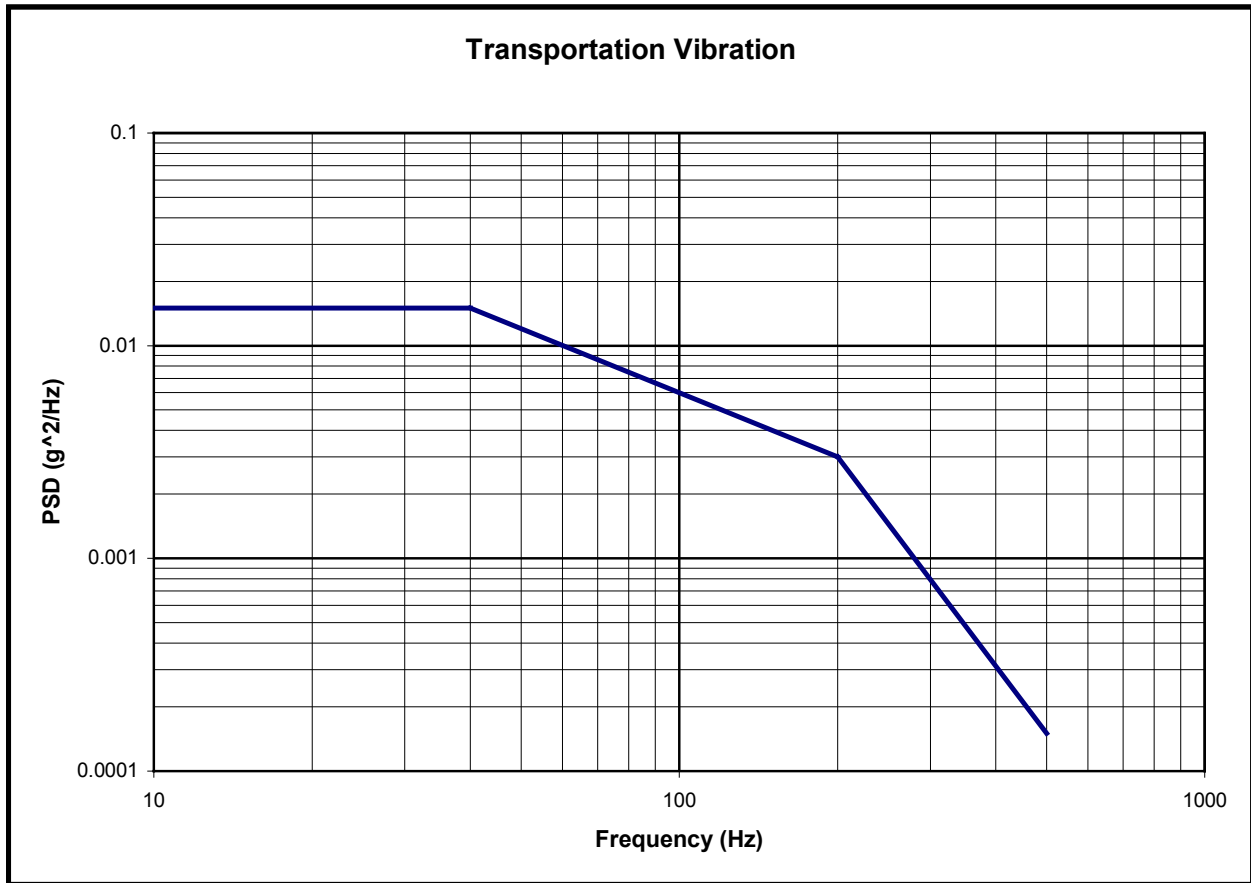
The Item shall operate as specified herein after exposure to the following magnetic fields: 1600 amperes per meter for a steady-state magnetic field; 1600 amperes per meter per second for a changing magnetic field.

3.2.5.3.2 Electromagnetic vulnerability (EMV)

This requirement shall be satisfied by the CS103 testing of Table VIII.

TABLE VII. Hot-Dry temperature cycling

Relative Time (Hrs.)	Temperature (°C)
00	35
01	34
02	34
03	33
04	33
05	34
06	37
07	42
08	47
09	56
10	66
11	73
12	78
13	82
14	85
15	82
16	78
17	66
18	56
19	52
20	46
21	41
22	37
23	35



Breakpoints	
Frequency (Hz)	PSD (g ² /Hz)
10	0.015
40	0.015
200	0.003
500	0.00015
GRMS =1.27	

Notes:

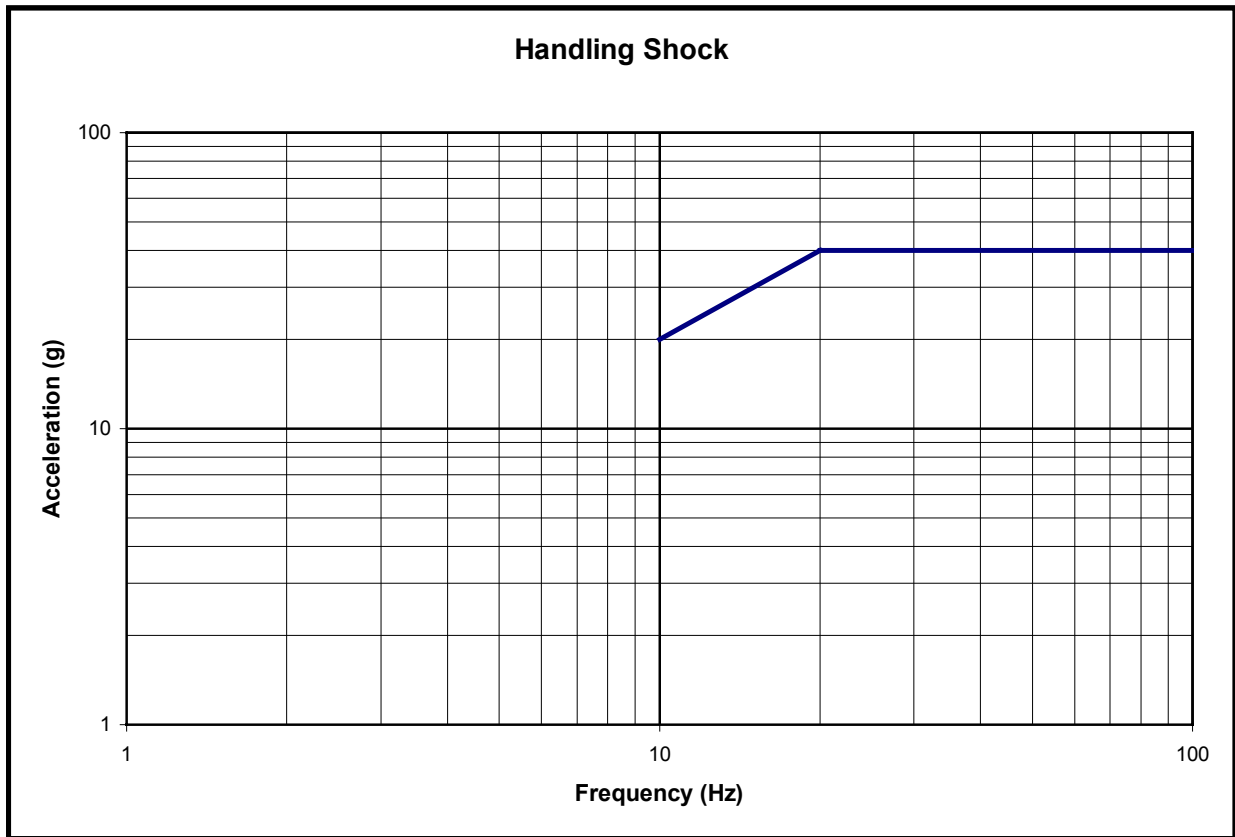
For each axis:

1 hour at -45°C

1 hour at ambient

1 hour at +50°C

FIGURE 7. Transportation Vibration.

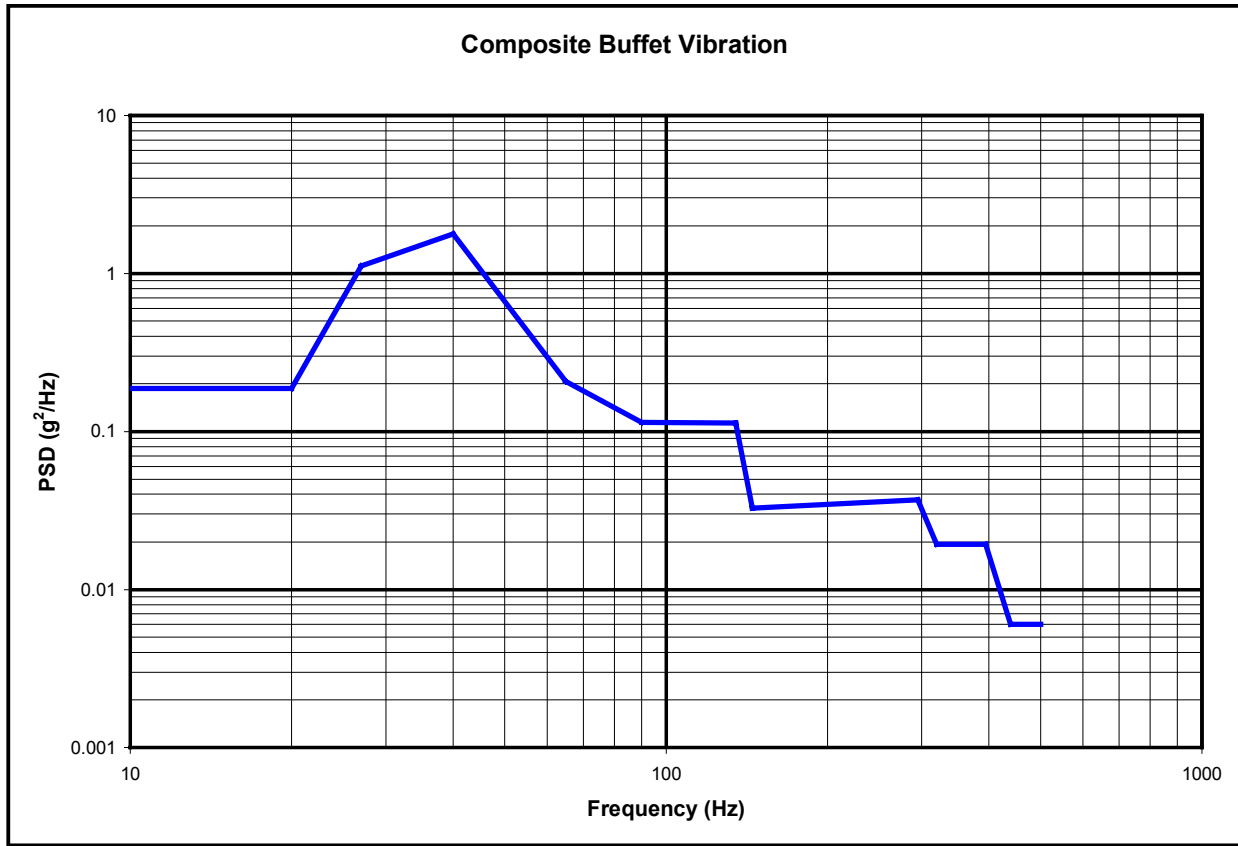


Breakpoints	
Frequency (Hz)	Acceleration (g's)
10	20
20	40
100	40
Q=10	

Notes:

For each axis, each direction:
 2 shocks at -45°C
 2 shocks at ambient
 2 shocks at +50°C

FIGURE 8. Handling Shock.



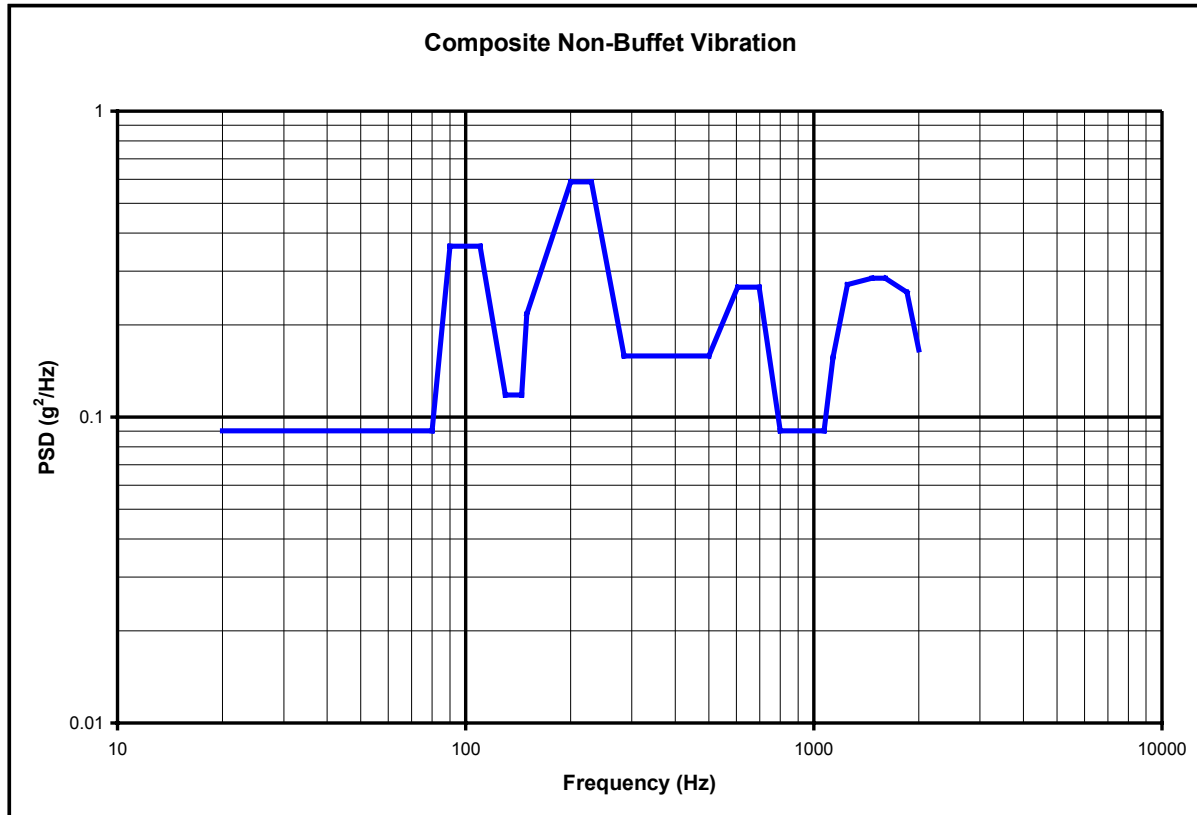
Breakpoints	
Frequency (Hz)	PSD (g ² /Hz)
10	0.1867
20	0.1867
27	1.1202
40	1.7785
65	0.2065
90	0.1147
135	0.1132
145	0.0327
295	0.037
320	0.0194
395	0.0194
440	0.006
500	0.006
GRMS = 7.67	

Notes:

For each axis:

- 1 minutes at -40°C
- 1 minutes at ambient
- 1 minutes at +85°C

FIGURE 9. Composite Buffet Vibration.

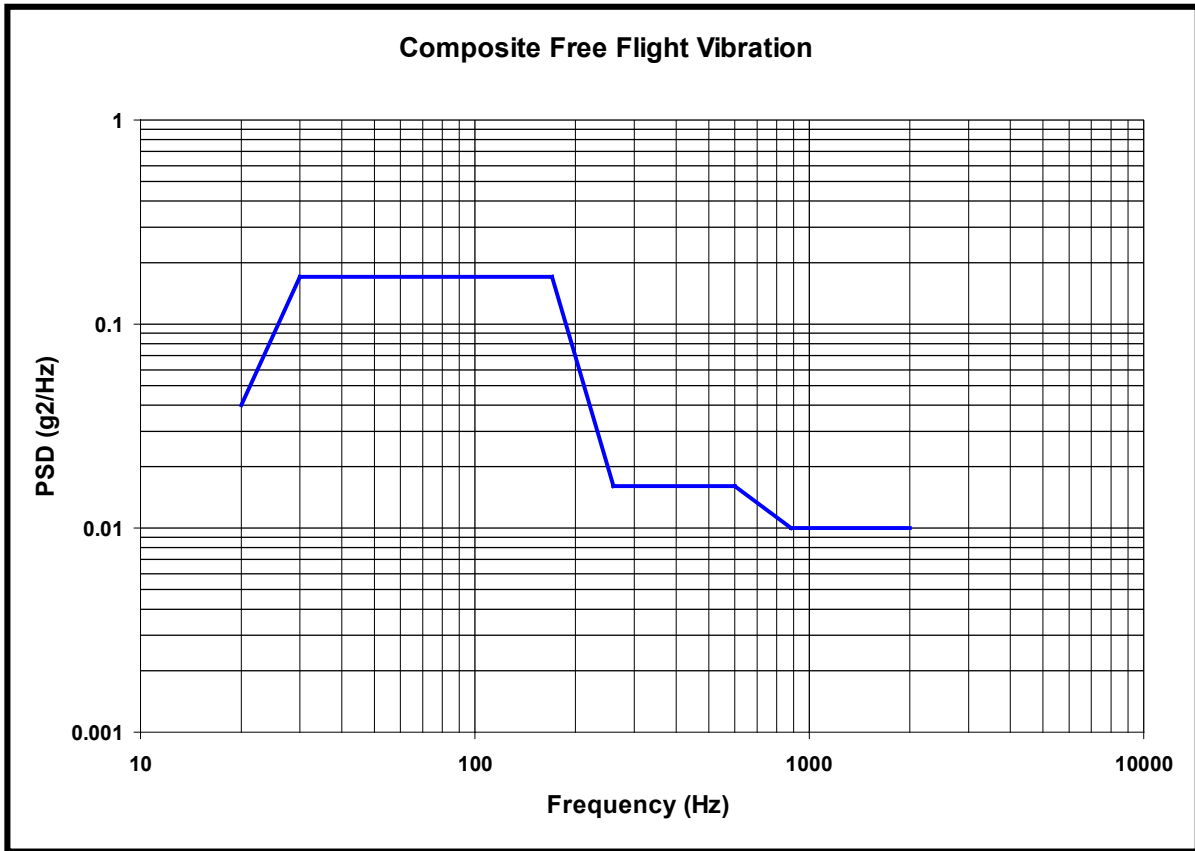


Notes:

For each axis:

- 10 minutes at -40°C
- 10 minutes at ambient
- 10 minutes at +85°C

FIGURE 10. Composite Non-Buffer Vibration.



Breakpoints	
Frequency (Hz)	PSD (g ² /Hz)
20	0.04
30	0.17
170	0.17
260	0.016
600	0.016
880	0.01
2000	0.01
GRMS = 7.09	

Notes:

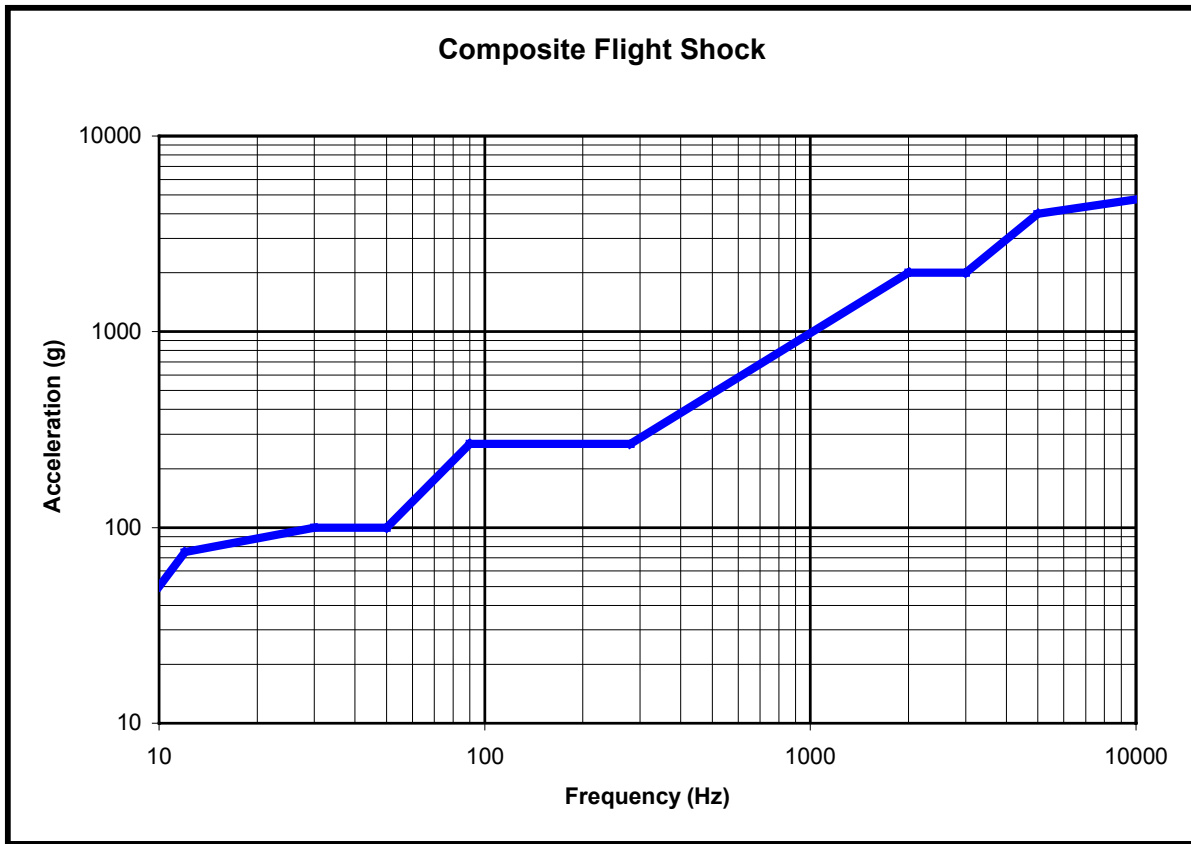
For each axis:

7 minutes at -40°C

7 minutes at ambient

7 minutes at +85°C

FIGURE 11. Composite Free Flight Vibration.



Breakpoints	
Frequency (Hz)	Acceleration (g)
10	50
12	75
30	100
50	100
90	267.5
280	267.5
2000	2000
3000	2000
5000	4000
10000	4750
Q = 10	

Notes:

For each axis, each direction:

1 series at -40°C

1 series at ambient

1 series at +85°C

FIGURE 12. Composite Flight Shock.

TABLE VIII. EMI/EMC Requirements

Parameter	Description, Limits, MIL-STD-461E
CE102	Conducted Emissions, Power Leads, 10 KHz to 10 MHz.
CE106	Conducted Emissions, Antenna Terminal, 10 KHz to 40 GHz.
CS101 Note 1	Conducted Susceptibility, Power Leads, 30 Hz to 50 kHz, 1 Volt
CS103	Conducted Susceptibility, Antenna Port, Intermodulation 15 KHz to 40 GHz. The out-of-band signal levels used for CS103 shall be 66 dB above the threshold level of the receiver.
CS104	Conducted Susceptibility, Antenna Port, Rejection of Undesired Signals, 30 Hz to 20 GHz. Two signal method. The out-of-band signal levels used for CS104 shall be 80 dB above the level producing the standard reference output or zero dBm where real identifiable signals are shown to be present.
CS114	Conducted Susceptibility, Bulk Cable Injection, 10 kHz - 200 MHz.
CS115	Conducted Susceptibility, Bulk Cable Injection, Impulse Excitation.
RE102	Radiated Emissions, Electric Field, 10 kHz to 18 GHz.
RS103	Radiated Susceptibility, Electric Field, 10 kHz to 18 GHz. 200 Volt/meter - Survival only.

NOTE 1: Failure of the Item to maintain track on all satellites being tracked in accordance with 3.2.1.2 shall constitute a failure of the susceptibility requirement.

3.3 Design and construction

3.3.1 Materials and parts

3.3.1.1 Materials

3.3.1.1.1 Restricted materials.

Encapsulating compounds that are subject to reversion under any combination of temperature and humidity shall not be used in the manufacture of the Item. Silicone elastomers and other elastomers and encapsulants adversely affected by JP-10 (ref.: 3123AS1088) shall not be used. The Item shall not contain magnesium or mercury. Polyimide (Kapton) insulated wire shall not be used in the Item, but Kapton may be used for flex harnesses. If silicone rubber is used, the material shall be a fluorinated compound for compatibility with fuels specified in 3123AS1088 (JP-10). The use of potting material in connectors shall be prohibited except when a nonreverting compound is used as a backshell filler in molded cable. Connectors that might be subject to water intrusion shall be rendered water resistant via use of nonreverting potting compound. For structural applications, free-machining stainless steels (e.g., AISI 303 or 416) shall not be used in the Item.

3.3.1.1.2 Moisture and fungus resistance

Materials that are nutrients for fungus shall not be used.

3.3.1.1.3 Dissimilar metals

Dissimilar metals, as defined in MIL-STD-889, shall not be used in direct contact with each other unless they have been treated to prevent galvanic corrosion. Additional organic finishing or barrier tapes may be used, subject to the requirements and restrictions of Standard Practice MIL-STD-7179.

3.3.1.2 Parts

3.3.1.2.1 Castings

Castings shall conform to SAE-AMS-STD-2175 Class 2 or 4. Class 2 castings shall: 1) conform to the requirements of SAE-AMS-A-21180, AMS 5342 or AMS 5343; 2) have a minimum margin of safety of zero; and 3) require an approved static test of one finished production part. Class 4 castings shall have a minimum margin of safety of 2.00 based on minimum guaranteed yield and ultimate mechanical properties. If minimum guaranteed properties are not available then an approved static test to destruction may be used to demonstrate Class 4 margin of safety. For the shock environments specified herein, the 2.00 factor for margin of safety does not apply.

3.3.2 Mounting

The Item shall be capable of being mounted in any orientation.

3.3.3 Electrical/Electrostatic properties

3.3.3.1 Grounding, bonding and shielding

The DC resistance between all faying surfaces shall be no greater than 2.5 milliohms. The ground return path for all power and signal circuits shall be through wiring conductors in the wiring harness. The structure shall not be used as a current-carrying conductor, except that the RF ground path may be through the coaxial cable shields.

3.3.3.2 Isolation requirements

There shall be not less than 100 kilo-ohms DC resistance between the power returns and chassis, and between power return and signal return.

3.3.3.3 Electrical conductivity

Protective coatings on the Item and its component mounting surfaces shall offer a low impedance path to RF currents. Mating surfaces to aluminum through which electrical bonding is required shall have metal-to-metal contact and be protectively finished to provide a resistance of not greater than 5 milliohms per square inch.

3.3.3.4 Electrostatic discharge (ESD)

The Item design shall provide ESD protection for sensitive electrical and electronic circuitry using MIL-STD-1686 as a guide.

3.3.4 Identification and marking

Product marking shall be in accordance with MIL-STD-130. Product marking shall contain, as a minimum, the following information:

- a. Part Number
- b. Serial Number
- c. Item Name
- d. Nomenclature (see 3.2.1.5.6.6)

3.3.5 Interchangeability

The Item shall be an interchangeable item as defined in 4.3.5.

3.3.6 Transportability

The Item shall be transportable by motor vehicle, rail freight, cargo vessel, or cargo aircraft. When the Item is transported by one of these means, the requirements specified in Section 5 shall apply.

3.3.7 Workmanship

The JTU shall be constructed and finished with a quality of workmanship as set forth in MIL-HDBK-454. Particular attention shall be given to neatness and thoroughness of soldering, wiring, impregnation of coils, loose parts, marking of parts and assemblies, freedom from burrs, sharp edges, dirt, chips, other foreign matter, and visible defects that are likely degrade the performance of the JTU.

3.3.8 Safety

The JTU shall be designed to preclude hazards to personnel and equipment in handling, testing, maintenance, and operational use, in accordance with MIL-STD-1472.

3.3.9 Human performance/human engineering

The JTU design shall follow the guidelines of MIL-STD-1472 and MIL-HDBK-46855.

3.4 Qualification

When required by the purchase order, the Item shall be subjected to qualification in accordance with 4.3.2.

3.5 Environmental stress screening (ESS)

ESS shall be accomplished on each item during Acceptance Testing in accordance with 4.3.3.2.

3.6 Acronyms and definitions

The Acronyms and definitions of Section 6.3 shall be applicable throughout this Specification.

4.0 VERIFICATION PROVISIONS

4.1 General

The verification methods used to verify the Item's ability to meet the design, performance, construction, and preparation for delivery requirements specified herein shall be determined by the Contractor. In general, verification shall be accomplished by test, analysis, inspection or demonstration as defined in this section. Items being tested shall not be adjusted, repaired, or maintained unless specifically permitted by the Government. When authorized by the Government to make corrections and after corrections are made, all tests deemed necessary by the Government shall be performed to verify that the Item meets the specification requirements. Verification of requirements shall be as specified in Table IX. Tables IX and X are pertinent throughout this section and are therefore collated at the end of this section.

4.1.1 Responsibility for verification

Unless specified in the acquisition documents, the Contractor is responsible for the performance of all verification requirements as specified herein. Except as otherwise specified in the acquisition documents, the Contractor may use its own or any other facilities suitable for the performance of the verification requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in this specification where such inspections are deemed necessary to ensure that supplies and services conform to prescribed requirements.

4.1.1.1 Test plans and procedures

The Contractor shall be responsible for the preparation of an overall Test Plan showing the methodology for compliance with this section. The Test Plan and /or Procedures shall contain complete descriptions of the test hardware and test setup. The Test Plan shall be approved by the Government prior to further acquisition actions. Any costs incurred by the Contractor prior to the approval of the Test Plan shall be at the Contractor's risk. After approval of the Test Plan, the Contractor shall be responsible for the preparation of detailed Test Procedures for the verification actions of this section. The Test Procedures shall be available for review by the Government.

4.1.2 Responsibility for compliance

The Item shall meet all requirements of Section 3. The verification requirements set forth in this specification shall become a part of the Contractor's overall verification system or Quality Assurance (QA) Program. The absence of any verification requirements in the specification shall not relieve the Contractor of the responsibility of ensuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling inspection, as part of manufacturing operations, is an acceptable practice to ascertain conformance to requirements, however, this does not authorize submission of known defective material, either indicated or actual, nor does it commit the Government to accept defective material.

4.1.3 Test equipment and facilities

Calibration of all measuring and inspection equipment that controls the accuracy of test equipment and facilities shall be in accordance with ANSI/NCSL Z540-1-1994. Calibration shall be traceable to the National Institute of Standards and Technology. The Contractor shall ensure that test facilities of sufficient quality and quantity are established and maintained to permit performance of required tests.

4.2 Methods of verification

The following verification methods shall be used to verify compliance with Section 3 requirements.

4.2.1 Analysis

An analysis consists of the review and discussion of test and /or analytical data; performance of technical or mathematical evaluation; use of mathematical models or simulations; or review of algorithms, charts, or circuit diagrams.

4.2.2 Demonstration

A demonstration consists of a method by which characteristics of the Item may be observed, without the use of quantitative measurement equipment, in order to evaluate empirically the adequacy with which the Item conforms to specified requirements.

4.2.3 Examination/Inspection

An examination consists a visual inspection of the Item, reviewing descriptive documentation, and comparing the appropriate characteristics with predetermined standards to determine conformance to requirements without the use of laboratory equipment or procedures. Examination may include documents, the comparison of documents, or comparison of a document to the equipment or item it describes. The terms examination and inspection are used interchangeably in this Specification.

4.2.4 Test

A test consists of a quantitative indication of compliance with specified requirements and shall be accomplished through systematic exercising of the Item under appropriate conditions and the collection and evaluation of quantitative data.

4.3 Verification procedures

4.3.1 Unit functional test

The Unit Functional Test shall consist of a test sequence that verifies all the Section 3 elements in Table IX. This test is the basic methodology for verifying the proper performance of the Item. As such it is utilized throughout the Acceptance and Qualification Testing. A valid Functional Test requires that all the Section 3 requirements be verified by producing data that demonstrates the proper performance of the unit. In order to reduce test time, a subset of these test requirements may be developed that indicates the proper performance of the unit without recording (or separately “testing to”) each requirement element. In addition, many functional elements depend on the proper functioning of previous steps in the logic, and therefore the measurement of the “end” result can be used to imply or include the proper function of such sub-elements. Such a “satisfactory” performance test procedure, hereafter called “Minimum Functional Test”, shall be accompanied with a supporting analysis and be approved by the Government. The units in the Qualification Sample shall successfully complete all the required elements indicated in Table IX at some time during Qualification Testing. Table IX indicates by an “MF” those items considered as the minimum items required for a “Minimum Functional Test”

4.3.2 Qualification

The Qualification of the unit shall consist of the successful completion of all the items included in Table IX utilizing the indicated methodology to the satisfaction of the Government. Qualification Procedures (to include analyzes and demonstrations) shall be conducted on a sample which shall be representative of production hardware, fabricated with production tooling and processes, and at the highest level of assembly deliverable to the Government (this does not preclude tests at lower levels of assembly, where deemed necessary).

4.3.2.1 Qualification testing

Qualification Testing refers to a series of specific environmental tests conducted on a designated sample of the Item. Prior to Qualification Testing, the Qualification Sample shall have successfully completed the Acceptance Test sequence of 4.3.3 below. Qualification tests shall be as indicated in Table IX with a “Q”, and shall be performed on the sample to establish the design integrity of the Item.

4.3.2.1.1 Sample size

Unless otherwise specified in the contract, the qualification sample size shall be statistically significant per the guidelines of MIL-HDBK-781. The Government shall approve the Sample size and the number of specific units of the Sample to be subjected to the entire Qualification Test series.

4.3.2.1.2 Qualification failure criteria

Failure of any unit of the Qualification test sample to pass any of the tests of the Qualification Series indicated in Table IX shall be cause for stopping the Qualification Tests. Any failure must be analyzed to determine the root cause of the failure and the impact on the tested design before continuing with the Qualification process. Any corrective action resulting in design changes and/or parts replacement shall require a retest sequence as approved by the Government.

4.3.3 Acceptance test sequence

The Acceptance Test sequence consists of the QA Inspections, Unit Functional Tests (4.3.1) and ESS. Acceptance tests shall be performed on each Item supplied under the contract to verify that the Item meets the requirements listed in Table IX under Acceptance Test Series. Acceptance or approval of material during the course of manufacture shall not be construed as a guarantee of its acceptance in the finished product. This test sequence constitutes the minimum acceptable testing prior to delivery of an Item. Failure of any Item to pass any of the acceptance tests in Table IX shall be cause for rejection of the Item.

4.3.3.1 Quality Assurance “QA” inspections

Each Item presented for acceptance shall be physically and/or visually examined to ensure that it meets all requirements of workmanship, cleanliness, weight, dimensions, finish, bonding, plating, marking and identification as specified herein and on the drawings for the Item. Failure to pass this examination shall cause the Item to be rejected. This inspection should include certification of an in-process Quality inspection performed at certain intervals during fabrication of the Item. Requirements for the QA Inspection are indicated in Table IX with a “QA”.

4.3.3.2 Environmental stress screening testing

Each Item presented for acceptance shall be subjected to ESS in accordance with the guidelines described in TE-000-AB-GTP-020 or other similar stress screening for material acceptability and workmanship qualities as agreed to by the Government and augmented by the contract. Failure of the Item to meet the requirements of 3.5 shall be cause for rejection. The requirement for the ESS Testing is indicated in Table IX with a “A” as part of the Acceptance Test Sequence.

4.3.3.3 Acceptance failure criteria

Failure of the unit to pass any of the tests of this paragraph shall be cause for rejection. Rejected units shall not be tested further in the Qualification cycle until a determination of the cause of the failure is made.

4.3.4 Tests

4.3.4.1 Functional test

The Functional test (4.3.1) shall be of sufficient scope and accuracy to ensure that the Item has complied with the Section 3 requirements specified in Table IX. Unless otherwise specified herein, specific functional tests and conditions shall be defined by a test plan that shall be subject to approval by the Government. The functional tests shall be conducted at nominal voltage unless otherwise specified herein. Nominal voltage shall be defined as 28 ± 0.5 Vdc

4.3.4.2 Environmental tests

Unless otherwise specified herein, test methods and tolerances shall be in accordance with MIL-STD-810F. The Test Plan submitted by the Contractor shall specify the particular Method and Procedure from Mil-STD-810F for each environmental test. These Methods can be “tailored” while maintaining the integrity of the verification requirements.

4.3.4.2.1 Temperature testing

For all operating temperature-related tests specified herein, the component mounting surface of the Item shall be the location at which the test/soak temperature applies. If the Item is designed to be mounted on several of the surfaces, only one surface need be tested. For non-operating (logistic) temperature tests specified herein, the temperature sensor shall be placed on an exposed side of the Item in order to measure the temperature of the proximate surrounding air.

4.3.4.2.2 Resonant frequency determination

Prior to any vibration testing specified herein (ESS Test), the Item's resonant frequencies shall be determined. This shall only be required on a significant sample of initial units presented for acceptance. For resonant frequency determination by test, the output(s) shall be measured on compliant structure(s) of the test Item where the maximum response(s) are anticipated. The frequencies can be described using modal equipment. If modal equipment is not used, then either sinusoidal inputs (determined by varying the frequency of applied sinusoidal vibration through the range of 5-2000-5 Hz at reduced levels, but with sufficient amplitude, to excite the Item) or random inputs may be used. For resonant frequency determination by analysis, the Item shall be modeled in sufficient detail to define the lowest resonant frequency.

4.3.4.2.3 Non-operating environmental tests

Unless otherwise specified, the Item shall be unpacked and in the nonoperational mode for these tests. Between each non-operating environmental test, the Item shall be subjected to the Unit Functional Test (4.3.1). Failure of the Item to successfully meet the requirements of the Functional Test shall constitute a failure of the preceding non-operating environmental test. In addition to the Functional Test, an inspection of the Item shall be required to determine if any structural damage and/or deformation occurred as a result of the applied environment. Any such indication of damage shall be cause for the failure of the test. Alternately, a single Functional Test can be run after the Item has been subjected to a sequence of the non-operating conditions, however, care must be exercised to examine the unit for damage after each individual environment. For such sequential testing, consideration must be given to the fact that such grouping of environmental tests may make it difficult to determine exactly which environment caused a subsequently discovered functional failure.

4.3.4.2.4 Operating environmental tests

For these tests the Item shall be installed in a test fixture which simulates the configuration of the Item when installed in a missile. The Item shall be powered and operating for these tests and shall meet the performance requirements for the Unit Functional Test (4.3.1).

4.3.4.2.5 Altitude and pressure rate of change

For these tests the Item shall be installed in a test fixture which simulates the configuration of the Item when installed in a missile. The Item shall be powered and operating for these tests and shall meet the performance requirements for the Unit Functional Test (4.3.1). Specific procedures for verifying these requirements shall be developed by the Contractor in concert with the Government.

4.3.4.3 Electromagnetic tests

4.3.4.3.1 EMI and EMV verification

Compliance with the EMI and EMV requirements of 3.2.5.3 and Table VIII shall be verified according to the test procedures of MIL-STD-461. The unit shall be tested in a EMI shielded test chamber in a configuration that simulates as closely as possible the actual flight environment by mounting with representative RF antenna leads, power input and data output cabling leading to the respective connectors.

4.3.4.3.1.1 EMI filtering

The GSU RF input requires an inline EMI filter/limiter/amplifier assembly (FLA) as part of the air vehicle GPS antenna and input cabling. Therefore this testing shall be done with a representative EMI FLA and RF cabling in place.

4.3.4.3.2 Magnetic field tests

Compliance of the Item with the magnetic field requirements of 3.2.5.3.1 shall be verified by test. (A suggested test procedure is DOD-STD-1399/070.)

4.3.4.3.3 Grounding, bonding and shielding

The requirements of 3.3.3.1 shall be verified by test and inspection.

4.3.4.3.4 Electrical isolation tests

With all power return leads connected together and all signal return leads of any specific voltage connected together, measure the resistance between the two. Failure of the Item to meet the requirements of 3.3.3.2 shall be cause for rejection.

4.3.4.3.5 Electrical conductivity verification

The requirements of 3.3.3.3 shall be verified by inspection.

4.3.4.3.6 ESD Verification

The requirements of 3.3.3.4 shall be verified by analysis and inspection using the methods of MIL-HDBK-263.

4.3.5 Interchangeability

The Item must possess the functional and physical characteristics to be equivalent in performance, reliability, and maintainability to another item of similar or identical identification. The Item shall be capable of being exchanged for another of like identification without selection for fit or performance, and without alteration of the Item itself or of adjoining items, except for adjustment. This requirement shall be verified by inspection and/or demonstration.

4.3.6 Reliability

4.3.6.1 MFHBF

The MFHBF and other Reliability verifications of 3.2.3 shall utilize the methodology in MIL-HDBK-217 with no stress ratios greater than 1.0.

4.3.7 Maintenance testing

4.3.7.1 Status words

Three pins are available on the data connector (J2) for the output of system health status indications.

4.3.7.2 Verification prior/after installation

Verification and validation of any maintenance or Go/No-go procedures incorporated in the design shall be done by a special demonstration separate from the Qualification Testing.

4.3.8 Operating life

The requirements of 3.2.3.3 shall be verified by analysis.

TABLE IX. Verification Requirements Matrix

Requirement Key			
Verification Level		Method	
A	Acceptance	A	Analysis
Q	Qualification	D	Demonstration
S	Special, Separate	I	Inspection
		QA	QA Inspection
		T	Test
		N/A =	

Section 3.0	Section 4.0	Parameter	Level	Method
3.0		Requirements		
3.1		Item Definition		
3.1.1	4.3.2.1	Interface Definition	Q	D
3.1.2		Input Power		
3.1.2.1	4.3.2.1	Steady-State Voltages	A&Q	T
3.1.2.2	4.3.2.1	Out-of-Range Voltage	A&Q	T
3.1.2.3	4.3.2.1	Power Consumption	A&Q	T
3.1.2.4	4.3.2.1	Spike Voltage	Q	D/A
3.1.2.5	4.3.2.1	Step Voltage Characteristics	Q	D/A
3.1.2.6	4.3.2.1	Back-Electromotive Force (EMF)	Q	D/A
3.1.2.7	4.3.2.1	Short Circuit Protection	Q	T
3.1.2.8	4.3.2.1	Polarity Protection	Q	T
3.2		Characteristics		
3.2.1		Performance		
3.2.1.1	4.3.3	Flight Environment	Q	A
3.2.1.2	4.3.3	GPS Operation	A&Q	T
3.2.1.2.1	4.3.3	GPS Latency	Q	A/T
3.2.1.3	4.3.3	Accuracy	A&Q	T
3.2.1.4		Inertial Measurement Unit (IMU)		
3.2.1.4.1	4.3.2.1	Operation	Q	T
3.2.1.4.2	4.3.2.1	IMU/JTU Orientation	Q	D
3.2.1.4.3		Requirements		
3.2.1.4.3.1	4.3.2.1	Activation Time	Q	T
3.2.1.4.3.2	4.3.2.1	Data	Q	T
3.2.1.4.3.3	4.3.2.1	Accelerations and Rates	Q	T
3.2.1.4.3.4	4.3.2.1	Accuracy	Q	T
3.2.1.4.3.4.1	4.3.2.1	Error Model	Q	A
3.2.1.4.3.5	4.3.2.1	Resolution	Q	T
3.2.1.4.3.6	4.3.2.1	Latency	Q	T

TABLE IX. Verification Requirements Matrix (Continued)

Section 3.0	Section 4.0	Parameter	Level	Method
3.2.1.4.3.7	4.3.2.1	Anti-aliasing	Q	T
3.2.1.4.3.8	4.3.2.1	Angular rate and acceleration sensors	Q	T
3.2.1.5		Data formatter		
3.2.1.5.1	4.3.2.1	Functional requirements	Q	T
3.2.1.5.2		External Data Processing		
3.2.1.5.2.1	4.3.2.1	Outputs	Q	T
3.2.1.5.2.2	4.3.2.1	Inputs	Q	T
3.2.1.5.2.3	4.3.2.1	Event Markers	Q	T
3.2.1.5.2.4	4.3.2.1	Signal levels	Q	T
3.2.1.5.3		Parallel data (61 bit) transfer protocol		
3.2.1.5.3.1	4.3.2.1	Block transfer mode	Q	T
3.2.1.5.3.2	4.3.2.1	Free running mode	Q	T
3.2.1.5.4	4.3.2.1	Time and sampling relationships	Q	T
3.2.1.5.5		Inputs		
3.2.1.5.5.1	4.3.2.1	GSU message	Q	T
3.2.1.5.5.2	4.3.2.1	GSU sample rate (EPS)	Q	T
3.2.1.5.5.3	4.3.2.1	IMU sample rate (VARF)	Q	T
3.2.1.5.5.4	4.3.2.1	IMU integration factor	Q	T
3.2.1.5.5.5	4.3.2.1	IMU accumulation factor	Q	T
3.2.1.5.6	4.3.2.1	JTU data message structure (TUMS)	Q	T
3.2.1.5.6.1	4.3.2.1	Source data field	Q	T
3.2.1.5.6.2	4.3.2.1	Status word	Q	T
3.2.1.5.6.3	4.3.2.1	GSU data	Q	T
3.2.1.5.6.4	4.3.2.1	IMU data structure	Q	T
3.2.1.5.6.4.1	4.3.2.1	Header	Q	T
3.2.1.5.6.4.2	4.3.2.1	Counter	Q	T
3.2.1.5.6.4.3	4.3.2.1	Accumulated data	Q	T
3.2.1.5.6.4.4	4.3.2.1	IMU Checksum	Q	T
3.2.1.5.6.5	4.3.2.1	TUMS Data rate	Q	T
3.2.1.5.6.6	4.3.2.1	TUMS Nomenclature	A	I
3.2.1.5.7	4.3.2.1	IMU Data processing	Q	T
3.2.1.5.7.1	4.3.2.1	IMU Calibration Factors	Q	A
3.2.1.5.7.2	4.3.2.1	Accumulated delta velocities	Q	T
3.2.1.5.7.3	4.3.2.1	Accumulated Quaternion values	Q	T
3.2.1.5.7.4	4.3.2.1	Computational requirements	Q	D
3.2.1.5.8	4.3.2.1	Failure monitoring	S	T/A
3.2.1.6	4.3.2.1	Erratic performance	Q	T

TABLE IX. Verification Requirements Matrix (Continued)

Section 3.0	Section 4.0	Parameter	Level	Method
3.2.2		Physical Characteristics		
3.2.2.1	4.3.3	Weight	A	QA
3.2.2.2	4.3.3	Envelope dimensions	A	QA
3.2.2.3	4.3.2.1	Structural Integrity	A&Q	T
3.2.2.3.1	4.3.2.1	Durability	Q	A
3.2.2.3.2	4.3.4.2.2	Resonance	Q	T
3.2.2.4	4.3.2.1	Strength and rigidity	Q	A
3.2.3	4.3.6	Reliability		
3.2.3.1	4.3.6.1	Mean flight hours between failures	Q	A
3.2.3.2	4.3.6.1	Operational reliability	Q	A
3.2.3.3	4.3.8	Operating life	Q	A
3.2.4		Maintenance		
3.2.4.1	4.3.2.1	Scheduled maintenance	Q	A/D
3.2.4.2	4.3.2.1	Maintainability	Q	A
3.2.5	4.3.4.2	Environmental Conditions		
3.2.5.1	4.3.4.2.3	Non-operating Environmental Conditions		
3.2.5.1.1	4.3.4.2.1	Low Temperature	Q	T
3.2.5.1.2	4.3.4.2.1	Hot-Dry Temperature Cycling	Q	T
3.2.5.1.3	4.3.4.2.3	Shock – Transit Drop	Q	T
3.2.5.1.4	4.3.4.2.3	Transportation Vibration	Q	T
3.2.5.1.5	4.3.4.2.3	Handling Shock	Q	T
3.2.5.2	4.3.4.2.4	Operating Environmental Conditions		
3.2.5.2.1	4.3.4.2.1	Low Temperature	Q	T
3.2.5.2.2	4.3.4.2.1	High Temperature	Q	T
3.2.5.2.3	4.3.4.2.5	Maximum Pressure	Q	T
3.2.5.2.4	4.3.4.2.5	Altitude	Q	T
3.2.5.2.5	4.3.4.2.5	Pressure Rate of Change	Q	T
3.2.5.2.6	4.3.4.2.4	Relative humidity	Q	T
3.2.5.2.7	4.3.4.2.4	Acceleration	Q	T
3.2.5.2.8	4.3.4.2.4	Composite vibration	Q	T
3.2.5.2.9	4.3.4.2.4	Composite Flight Shock	Q	T
3.2.5.2.10	4.3.4.2.3	Explosive Atmosphere	Q	T
3.2.5.3	4.3.4.3	Electromagnetic Environments (EMC/EMI)		
Table VIII	4.3.4.3.1	EMI Environments	Q	T
3.2.5.3.1	4.3.4.3.2	Magnetic Fields	Q	T
3.2.5.3.2	4.3.4.3.1	Electromagnetic Vulnerability (EMV)	Q	T

TABLE IX. Verification Requirements Matrix (Continued)

Section 3.0	Section 4.0	Parameter	Level	Method
3.3		Design and Construction		
3.3.1		Materials and Parts		
3.3.1.1		Materials		
3.3.1.1.1	4.2.3	Restricted Materials	Q	I
3.3.1.1.2	4.2.3	Moisture and Fungus Resistance	Q	A
3.3.1.1.3	4.2.3	Dissimilar Metals	Q	I
3.3.1.2		Parts		
3.3.1.2.1	4.2.3	Castings	Q	I
3.3.2	4.2.3	Mounting	Q	D/I
3.3.3		Electrical/Electrostatic Properties		
3.3.3.1	4.3.4.3.3	Grounding, Bonding and Shielding	Q	T/I
3.3.3.2	4.3.4.3.4	Isolation Requirements	Q	T
3.3.3.3	4.3.4.3.5	Electrical Conductivity	Q	T/I
3.3.3.4	4.3.4.3.6	Electrostatic Discharge (ESD)	Q	A/I
3.3.4	4.3.3.1	Identification and Marking	A	QA
3.3.5	4.3.5	Interchangeability	Q	D/I
3.3.6	4.2.3	Transportability	Q	I
3.3.7	4.3.3.1	Workmanship	A	QA
3.3.8	4.2.3	Safety	Q	I
3.3.9	4.2.3	Human Performance/Human Engineering	Q	I
3.4	4.3.2	Qualification		
3.5	4.3.3.2	ESS Testing	A	T
3.6		Acronyms and definitions	Q	D
A.2		Interface Description		
A.2.1	4.2.3	Mechanical	A	I
A.2.2	4.2.4	Electrical	A	T
B.2		Item Configurations		
B.2.1	4.2.3	Flat mounted configuration	A	I
B.2.2	4.2.3	Flange mounted configuration	A	I

TABLE X. Unit Functional Test Matrix

1. Verification methods of 4.3.1 and 4.3.4.1 apply
2. MF Tests are a sub-category of FF Tests.

Test		Requirements
FF	Full Functional	All Parameters
MF	Minimum	As Marked
S	Special, Separate	As Marked
		N/A = <input type="checkbox"/>

Section 3.0	Unit Parameter	Requirement
3.1.2	Input Power	MF
3.1.2.3	Power consumption	MF
3.2.1	Performance	
3.2.1.2	GPS operation	MF
3.2.1.2.1	GPS latency	FF
3.2.1.3	Accuracy	MF
3.2.1.4	IMU	
3.2.1.4.3.1	Activation Time	MF
3.2.1.4.3.2	Data	FF
3.2.1.4.3.3	Acceleration and angular rates	FF
3.2.1.4.3.4	Accuracy	MF
3.2.1.4.3.5	Resolution	MF
3.2.1.4.3.6	Latency	MF
3.2.1.4.3.7	Anti-aliasing	FF
3.2.1.4.3.8	Angular rate and acceleration sensor alignment	FF
3.2.1.5	Data formatter	
3.2.1.5.1	Functional requirements	MF
3.2.1.5.2	External Data Processing	
3.2.1.5.2.1	Outputs	MF
3.2.1.5.2.2	Inputs	MF
3.2.1.5.2.3	Event Markers	MF
3.2.1.5.2.4	Signal levels	MF
3.2.1.5.3	Parallel data (61 bit) transfer protocol	
3.2.1.5.3.1	Block transfer mode	MF
3.2.1.5.3.2	Free running mode	MF
3.2.1.5.4	Time and sampling relationships	MF

TABLE X. Unit Functional Test Matrix (Continued)

Section 3.0	Unit Parameter	Requirement
3.2.1.5.5	Inputs	
3.2.1.5.5.1	GSU message	MF
3.2.1.5.5.2	GSU sample rate (EPS)	MF
3.2.1.5.5.3	IMU sample rate (VARF)	MF
3.2.1.5.5.4	IMU integration factor	MF
3.2.1.5.5.5	IMU accumulation factor	MF
3.2.1.5.6	JTU data message structure (TUMS)	MF
3.2.1.5.6.1	Source data field	MF
3.2.1.5.6.2	Status word	MF
3.2.1.5.6.3	GSU data	MF
3.2.1.5.6.4	IMU data structure	MF
3.2.1.5.6.4.1	Header	MF
3.2.1.5.6.4.2	Counter	MF
3.2.1.5.6.4.3	Accumulated data	MF
3.2.1.5.6.4.4	IMU Checksum	MF
3.2.1.5.6.5	TUMS Data rate	MF
3.2.1.5.6.6	TUMS Nomenclature	MF
3.2.1.5.7	IMU Data processing	MF
3.2.1.5.7.1	IMU Calibration Factors	MF
3.2.1.5.7.2	Accumulated delta velocities	MF
3.2.1.5.7.3	Accumulated Quaternion values	MF
3.2.1.5.7.4	Computational requirements	MF
3.2.1.5.8	Failure monitoring	MF
3.2.1.6	Erratic performance	MF

5.0 PACKAGING

5.1 Preparation for delivery

When required in the contract or purchase order the Item shall be packaged in accordance with best commercial practices consistent with the physical handling, storage and transportation environments specified in 3.2.5 and subparagraphs.

5.2 Marking for shipment

Containers shall be marked and labeled in accordance with the instructions in the contract or purchase order.

6.0 NOTES

6.1 Intended Use

The JTU-II will be used to provide air vehicle GPS satellite data and inertial motion measurements via the vehicle telemetry system to a ground processing unit during flight testing on a test range.

6.1.1 Warm-up time

The JTU is not expected to be used without a warm-up period of at least 60 seconds prior to launch of the air vehicle.

6.2 Acquisition requirements

Acquisition documents should specify the following as applicable:

- a. Title, number, and date of this specification.
- b. Identify data source for JTU form, fit, and mounting requirements if other than Appendix A
- c. Requirement for qualification sample inspection.
- d. Number of qualification inspection samples required.
- e. Disposition of qualification inspection samples.
- f. Packaging requirements for delivery.
- g. Special packaging provisions.
- h. The TUMS output rate (see 3.2.1.5.5.2).
- i. The IMU Sample Rate (see 3.2.1.5.5.3).
- j. The Integration factor (see 3.2.1.5.5.4).
- k. The IMU Accumulation Factor (see 3.2.1.5.5.5).

6.3 Coordination with other documentation

Specific requirements of this specification have been coordinated with Raytheon, Inc. drawing 7030036, Interface Control Document for the Advanced Medium Range Air to Air Missile.

6.4 Acronyms, abbreviations and symbols

A	Analysis
BIT	Built in Test
C	Centigrade
cm	Centimeters
DC	Direct Current
dB	Decibel
deg	Degrees
E	Examination
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EMF	Electromagnetic Force
EMV	Electromagnetic Vulnerability
EPS	Epoch pulse strobe (Same as PPE)
ESS	Environmental Stress Screening
ft	Feet
FLA	Filter/limiter/amplifier
g	Acceleration in gravity units
Hr	Hours
GHz	GigaHertz
GND	Electrical Ground
GPS	Global Positioning System
GSU	GPS Sensor Unit
Hz	Hertz
ICD	Interface Control Document
IMU	Inertial Measurement Unit
JAMI	Joint Advanced Missile Instrumentation
JDP	JAMI Data Processor
JTU	JAMI TSPI Unit
Kbaud	Kilo baud rate

Kbit	Kilobits
KHz	Kilohertz
LED	Light Emitting Diode
LSB	Least Significant Bit
LVTTL	Low Voltage Transistor-Transistor Logic
m	Milli (unit prefix)
ma	Milliampere
MACM	Missile Application Condensed Measurements
MATM	Missile Application Time Message
mg	Milli “g” acceleration
MHz	MegaHertz
mm	Millimeter
mrad	Milliradian
ms	Millisecond
MFHBF	Mean Flight Hours Between Failure
MSB	Most Significant bit
NAWC	Naval Air Weapons Center
ns	Nano seconds
PPE	Pulse per GPS epoch (Same as EPS)
pps	Pulse Per Second
psd	Power spectral density
psia	Pounds Per Square Inch Absolute
PVTM	Position, Velocity, Time Message
QA	Quality Assurance
RF	Radio Frequency
Sec, sec	Seconds
T	Test
TM	Telemetry
TSPI	Time-Space-Position Information
TUMS	TSPI Unit Message Structure

Vdc,V,DC	Volts Direct Current
VARF	Variable Frequency
XOR	Logic “exclusive OR”
μs	Microseconds
√	Square root function

APPENDIX A EXTERNAL INTERFACE DOCUMENT

JAMI TSPI UNIT (JTU) EXTERNAL INTERFACE DOCUMENT

A.1 GENERAL

A.1.1 Scope

This appendix consists of the External Interface Control Document which defines the mechanical and electrical external interfaces of the Joint Advanced Missile Instrumentation (JAMI) Time-Space-Position Information (TSPI) Unit, referred to herein as the JTU or the Item. Mechanical configuration variations are covered in Appendix B.

A.1.2 Objective

The objective of this Appendix is to describe the JTU external interface. The complete interface to the host missile will be described in a document unique to each missile application.

A.2 INTERFACE DESCRIPTION

A.2.1 Mechanical

A.2.1.1 Description

See Figure 1 in the main specification. The mechanical interface consists of two external connectors, J1 and J2, one internal board-to-board connection, J3; and form and fit requirements.

A.2.1.1.1 RF Connector (J1)

This is the GSU J1 RF connector on a “flying lead” from the GSU that protrudes through the wall of the JTU when the GSU is assembled into the JTU. The requirements for this connector are in the GSU specification.

A.2.1.1.2 Data Connector (J2)

This shall be a 51-pin female MDM connector.

A.2.1.1.3 GSU/JTU Data Connector (J3)

This shall be a board-to-board connector as defined in the GSU Specification.

A.2.1.1.4 Form and fit

The enclosure shall measure no more than 4.58 x 2.70 x 1.10 inches for a volume of 13.37 cubic inches. Mounting configurations are covered in Appendix B.

A.2.2 Electrical

A.2.2.1 Connector GSU/JTU J1

This connector is defined in the GSU specification.

A.2.2.2 Connector J2

This connector is the major data/power connector for the JTU. It shall support RS-232, NRZ-L and parallel (16-bit) output formats. The connector shall support the TUMS output message and the discrete external Event Marker inputs. The connector shall support the data requirements as discussed in the Data Formatter Section of this Specification.

A.2.2.2.1 Pin assignments

J2 Power/Data connector pin assignments are as shown in Table AI.

TABLE AI. J2 Data/Power Connector Pin Assignments

Connector Pin	Signal	Remarks
J2-01	Chassis GND	Connected to J2U Case
J2-02	+28 VDC RTN	Return line for System Power
J2-03	Chassis GND	Not for Use
J2-04	None	Spare
J2-05	Receive Data	RS-232
J2-06	EVENT1+	RS-422 input
J2-07	EVENT1 -	RS-422 input
J2-08	Signal GND	
J2-09	VARF	TTL output
J2-10	NRZ-L Data Stream	TTL Serial data
J2-11	D00	Tri-state LVTTL output(LSB)
J2-12	D01	Tri-state LVTTL output
J2-13	D02	Tri-state LVTTL output
J2-14	D03	Tri-state LVTTL output
J2-15	D04	Tri-state LVTTL output
J2-16	D05	Tri-state LVTTL output
J2-17	D06	Tri-state LVTTL output
J2-18	DAT_STB-	LVTTL output
J2-19	+28 VDC	System Power
J2-20	+28 VDC	System Power
J2-21	Chassis GND	Not for Use
J2-22	Signal GND	Signal Ground for RS-232
J2-23	Transmit Data	RS-232
J2-24	EVENT2-	RS-422 input
J2-25	EVENT3-	RS-422 input
J2-26	1 PPE (EPS)	TTL output
J2-27	GPS BIT	Output to drive LED
J2-28	D07	Tri-state LVTTL output
J2-29	Signal GND	
J2-30	D08	Tri-state LVTTL output
J2-31	Signal GND	
J2-32	D09	Tri-state LVTTL output
J2-33	Signal GND	
J2-34	CHIP_SEL-	LVTTL input
J2-35	Signal GND	
J2-36	+28 VDC RTN	Return for System Power
J2-37	Chassis GND	Not for Use
J2-38	MODE_SEL	LVTTL input
J2-39	None	Spare
J2-40	EVENT2+	RS-422 input
J2-41	EVENT3+	RS-422 input
J2-42	Static BIT	Output to drive LED
J2-43	Dynamic BIT	Output to drive LED
J2-44	Fail BIT	Output to drive LED
J2-45	D10	Tri-state LVTTL output
J2-46	D11	Tri-state LVTTL output
J2-47	D12	Tri-state LVTTL output
J2-48	D13	Tri-state LVTTL output
J2-49	D14	Tri-state LVTTL output
J2-50	D15	Tri-state LVTTL output
J2-51	BLK_XFER-	LVTTL output

APPENDIX B UNIQUE ITEM SPECIFICATION

JAMI TSPI UNIT (JTU) UNIQUE ITEM SPECIFICATION

B.1 GENERAL

B.1.1 Scope

This appendix describes the configuration variations that constitute a unique item within the general JTU Specification description.

B.1.2 Objective

The objective of this Appendix is to define the allowable configurations under the JTU Specification. Each Item configuration shall have a unique Part Number identification under the JTU Part Number series.

B.2 ITEM CONFIGURATIONS

B.2.1 Flange mounted

The flange mounted configuration shall be as described in Drawing SK01-5430200, Figure B.1.

1



APPENDIX C COMPUTATIONAL REQUIREMENTS

JAMI TSPI UNIT (JTU) COMPUTATIONAL REQUIREMENTS

C.1 Discussion

The IMU sensor of the JTU is expected to generate accelerometer delta-v and gyro delta-theta outputs at a rate of 1000 Hz or higher. Because of TM bandwidth limitations, these raw values must be accumulated into equivalent delta-v and delta-theta values over longer intervals, so the down-linked TM data transmission rate can be reduced. Additionally, the ground processor shall be required to propagate the ground-computed trajectory solution across a TM data gap. During a TM data gap, the transmitted delta-v and delta-theta values are lost, and the ground-computed inertial solution cannot be advanced. At the end of the gap, new delta-v and delta-theta values are available, but the missing values during the gap can only be approximated by interpolation with potentially large errors. However, if cumulative inertial values are computed onboard the missile, then these transmitted cumulative values available before and after the gap can be differenced to obtain the summed deltas. This process will give a ground-computed solution that is propagated across the gap with good accuracy.

C.2 Algorithms

To meet the requirement for a ground-computed trajectory solution it is required that the high-rate delta-v and delta-theta be accumulated from the start time, correcting for conning and sculling, and output at an interval which is user selectable. The fidelity and response time of the JAMI ground processor will be dependent upon the design of these algorithms. Various algorithms for performing this accumulation have been investigated by the government and the results of these investigations and the algorithms can be made available to the contractor. The government desires that the contractor utilize a set of algorithms that will provide a solution with the required resolution and that this process is verifiable within a given margin.

C.3 Requirements estimation

For estimating the computational resources required for this algorithm, Table C1 provides a summary of the mathematical operations required per measurement cycle of 1000 Hz. This rate of 1000 Hz is used in this specification as an example only and is not a requirement.

TABLE C1. Math Operations Per Measurement

Routine	Add	Sub	Mult	Div	Comp	Int2Flt	Flt2Int	Flt2Flt	Cos	Sin	Sqrt
A	7	0	0	4	0	0	0	4	0	0	0
B	2	0	6	2	1	0	0	0	1	1	1
C	8	4	16	0	0	0	0	4	0	0	0
D	6	6	18	0	0	0	0	0	0	0	0
E	4	0	0	0	0	0	0	0	0	0	0
F	3	0	4	4	0	0	0	0	0	0	1
G	6	6	18	0	0	0	0	0	0	0	0
H	8	4	16	0	0	0	0	4	0	0	0
I	3	0	4	4	0	0	0	0	0	0	1
Totals	47	20	82	14	1	0	0	12	1	1	3

Estimated Total Operations per cycle - 181